ADMIRALTY MANUAL OF SEAMANSHIP 1964

VOLUME III

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B.R. 67(3), *Admiralty Manual of Seamanship, Volume III*, 1964, having been approved by My Lords Commissioners of the Admiralty, is hereby promulgated.

B.R. 67(3), dated 1951, is hereby superseded.

B.R. 2092, *Handling Ships* (Restricted), dated 1954, is also superseded hereby, and all copies are to be disposed of in accordance with the instructions in B.R. 1.

By Command of Their Lordships,

PREFACE

The *Admiralty Manual of Seamanship* is divided into three volumes. *Volume I* is the basic book of seamanship for officers and men joining the Royal Navy. *Volume II* contains more technical detail and is a general textbook and reference book for ratings seeking advancement and for junior officers. *Volume III* is intended mainly for officers. It covers such essential seamanship knowledge as the handling of ships, and also information on a variety of subjects that could be classed as advanced seamanship, such as aid to ships in distress.

The chapters in each volume are arranged in the following four Parts, dealing generally with the subjects shown:

PART I: *Ship Knowledge and Safety*. Types of ship and their construction; firefighting; stability; control of damage; lifesaving.

PART II: *Seamanship*. The uses of rope; rigging; sailing boats and power boats; anchors and cables; evolutions such as towing, salvage and lifting or moving heavy loads.

PART III: *Ship Organisation*. General organisation of a ship; naval communications; ceremonial; ship upkeep and ship husbandry.

PART IV: *Shiphandling and Navigation*. Steering; elementary navigation and pilotage; handling of ships in different conditions; the Rule of the Road.

It is hoped that the volumes may also prove useful outside the Royal Navy, to all who put to sea in ships or boats.

CONTENTS

PART I

SHIP KNOWLEDGE AND SAFETY

CHAPTER 1

Stability of Ships

The factors which affect the stability of a ship are outlined in Volume II. In this chapter stability is dealt with in more detail in order to show how the stability of a ship is determined, and how it can be restored or improved, under various conditions of loading or damage. A comprehensive treatment of the subject is given in B.R. 2171, *Ship A.B.C.D. Manual*, Vol. 2.

TRANSVERSE STABILITY

Righting moment

The following facts are basic to an understanding of stability (fig. 1–1):

1. The position of the centre of gravity G of a ship will vary with her condition of loading. If she is symmetrically loaded, it will lie somewhere on the middle plane of the ship.
2. If the ship moves under the influence of any external force (e.g. wind or wave), the position of the centre of gravity for any particular condition of loading will remain fixed, apart from a slight movement caused by the shifting of any liquids with a free surface.
3. The position of the centre of buoyancy B will lie directly below the centre of gravity when the ship is steady, but when the ship heels it will move to a position B_1 in the centre of the submerged volume of the ship.
4. The forces of weight and buoyancy are each equal to the displacement of the ship W, and they act vertically in opposite directions.
5. The force of buoyancy acting upwards through B_1 when the ship is heeled will produce a moment tending to right the ship, and this moment is calculated by multiplying the displacement W by the righting lever GZ, which is the horizontal distance between the forces of weight and buoyancy.

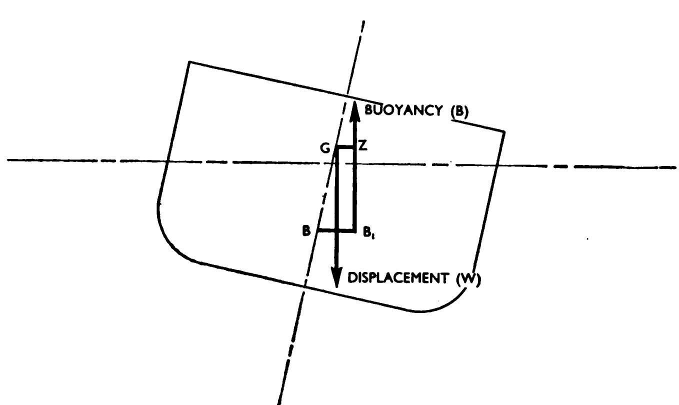


FIG. 1–1. Righting moment

6. The righting moment depends chiefly on the angle of heel and the movement of the centre of buoyancy; it will increase with an increase of the angle of heel up to a certain critical angle, but thereafter it will decrease with any further increase of the angle of heel, and will eventually change to a capsizing moment.

Transverse metacentre and transverse metacentric height

In most ships, for small angles of heel of up to about 10°, the line of action of the force of buoyancy B_1 will cut the middle line of the ship at a fixed point M which is called the ***transverse metacentre*** (fig. 1–2).

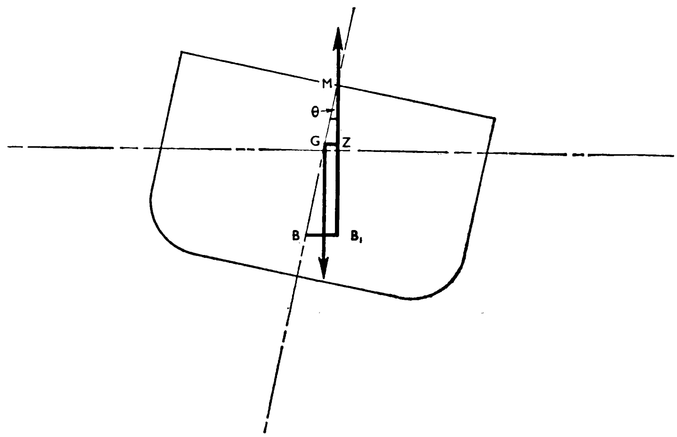


FIG. 1–2. Transverse metacentre and metacentric height

The height of the metacentre M above the centre of gravity G is called the ***metacentric height***; it gives a measure of the initial stability of the ship, i.e. her stability at small angles of heel.

Considering the triangle GMZ in fig. 1–2, the angle θ at its apex is equal to the angle of heel, and the righting lever GZ will be equal to $GM \sin \theta$. If the metacentric height GM is known, the righting moment can be found by multiplying the righting lever GZ by the displacement of the ship W.

When a ship is heeled, the position of her transverse metacentre depends upon the shape of her waterplane and on the position of the centre of buoyancy B_1, which in turn depends on the draught of the ship and the underwater shape of her hull. At angles of heel of over, say, 10° the position of the transverse metacentre will not be fixed but will change with the angle of heel, and the designer must arrange the dimensions of her hull to ensure not only a reasonable margin of initial stability at all normal conditions of loading, but also a reasonable margin of stability over the probable angles of heel to which the ship may roll in a heavy sea. In general it can be assumed that if a ship is of conventional form and has a reasonable margin of initial stability at all ordinary conditions of loading, she will also have sufficient stability to right herself from any angle to which she may be heeled in the normal course of events.

Position of transverse metacentre

The height of the transverse metacentre above the centre of buoyancy (*BM* in fig. 1–2) depends solely on the form of the ship at and below her waterline, and it will therefore vary with the beam of the ship, her waterplane area, her coefficient of fineness, and her draught. This is shown by the formula:

$$BM=\frac{I}{V}=k\frac{LB^3}{LBD}=k\frac{B^2}{D},$$

where:

k is a constant depending upon the underwater form of the ship;

L, B and D are the length, beam and draught, respectively, of the ship;

I is the transverse moment of inertia of the waterplane area about the middle line of the ship; and

V is the volume of the ship's displacement.

It will therefore be seen that the distance *BM* is directly proportional to the square of the beam, and inversely proportional to the draught.

The position of the metacentre is determined by the designer when he plans the ship, and as soon as the lines of her design are settled he constructs a ***metacentric diagram***, which shows the position of the metacentre for any draught at which the ship is likely to float. From the diagram it can be discovered what will be the height of the transverse metacentre above its corresponding centre of buoyancy, and what will be its height above the keel, for each of a number of possible waterlines.

Degree of transverse stability

The degree of initial stability, as measured by the ship's transverse metacentric height at any particular condition of loading, depends on the relative positions of her transverse metacentre and her centre of gravity. The position of the transverse metacentre is determined by the designer and so cannot be altered by the seaman; it depends entirely on the underwater shape of the hull and it will change only as the draught of the ship changes. The centre of gravity, however, depends largely on the disposition of the fuel, water, stores and any cargo or ballast which the ship may be carrying, and it can therefore be altered by the seaman to provide the necessary margin of initial stability.

A ship with a large transverse metacentric height has a high resistance to rolling forces, and so will roll with a short, rapid motion; such a ship is said to be ***stiff***. A ship with a small transverse metacentric height does not offer so much resistance to rolling, and so will roll with a long, slow motion; such a ship is said to be ***tender***.

A ship's initial stability, as measured by her transverse metacentric height, should not, however, be taken as a measure of her seaworthiness. A ship that is too stiff can be just as dangerous as one that is too tender, because rolling that is too rapid and violent may shift her cargo, carry away her masts, strain her hull and even unseat her machinery.

The degree of transverse stability is therefore arranged to suit a ship's characteristics and the duties or trade on which she is engaged. Passenger liners must not be too stiff, or the comfort of their passengers will suffer; nor should cargo

vessels be too stiff, or their cargo may shift when they are in a seaway. Warships, on the other hand, must usually be stiffer than merchant ships to ensure a reasonable margin of stability should they be flooded from underwater damage; but they must not be too stiff, or the accuracy of their gunfire may be impaired by too violent rolling. The stability of vessels intended for fixed routes, such as cross-Channel steamers, ocean liners and vessels sailing on inland waterways, is often designed to suit the kind of seas they will probably encounter, and this must be borne in mind if it is intended to use such vessels elsewhere.

Stability at large angles of inclination

The simple expression for the length of the stability lever GZ (shown in fig. 1–1), *viz.*, $GZ=GM \sin \theta$, applies only to small angles of inclination up to about 10° for ships of normal shape. At these small angles the line of action of the force of buoyancy can be taken to pass through a fixed point, but it does not do so at greater angles.

A series of intricate calculations is used to estimate the righting levers at different displacements for a series of angles of heel (usually every 15° from 15° to 90°). From the values thus obtained *cross curves of stability* are drawn for each angle of heel and these can be combined on a single graph, as shown in fig. 1–3. The large variations of displacement catered for do occur in a merchant ship at different conditions of loading.

A typical stability curve

From this graph *curves of statical stability*, sometimes known as *righting-lever* or GZ curves, can be drawn for specified conditions of loading. These curves give the length of the righting lever GZ for various angles of heel, and each shows graphically the degree of stability of the ship in the condition for which the curve was drawn.

A typical stability curve is shown in fig. 1–4 and its general features are described below.

1. At small angles of heel (up to about 10°) the curve is approximately a straight line, and the angle which it makes with the base line is governed by the metacentric height, since $GZ=GM \sin \theta$ when θ is small.
2. As the angle of heel increases above 10° the steepness of the curve increases, and it is steepest at the angle at which the freeboard deck-edge becomes immersed.
3. As the angle of heel increases still further the steepness of the curve decreases, until it becomes horizontal at an angle of heel called the *angle of maximum righting lever*.
4. Thereafter the curve descends, at first with increasing steepness and then at a steady angle of descent, until it crosses the base line at a point called the *vanishing angle*, at which there is no righting lever and beyond which a capsizing lever is set up. This point defines the limit of the *range of stability* of the ship for that particular condition of loading; it is sometimes called the *range*.

The angle of maximum righting moment is the largest angle of *steady heel* which a ship can take up without capsizing when inclined by a constant heeling

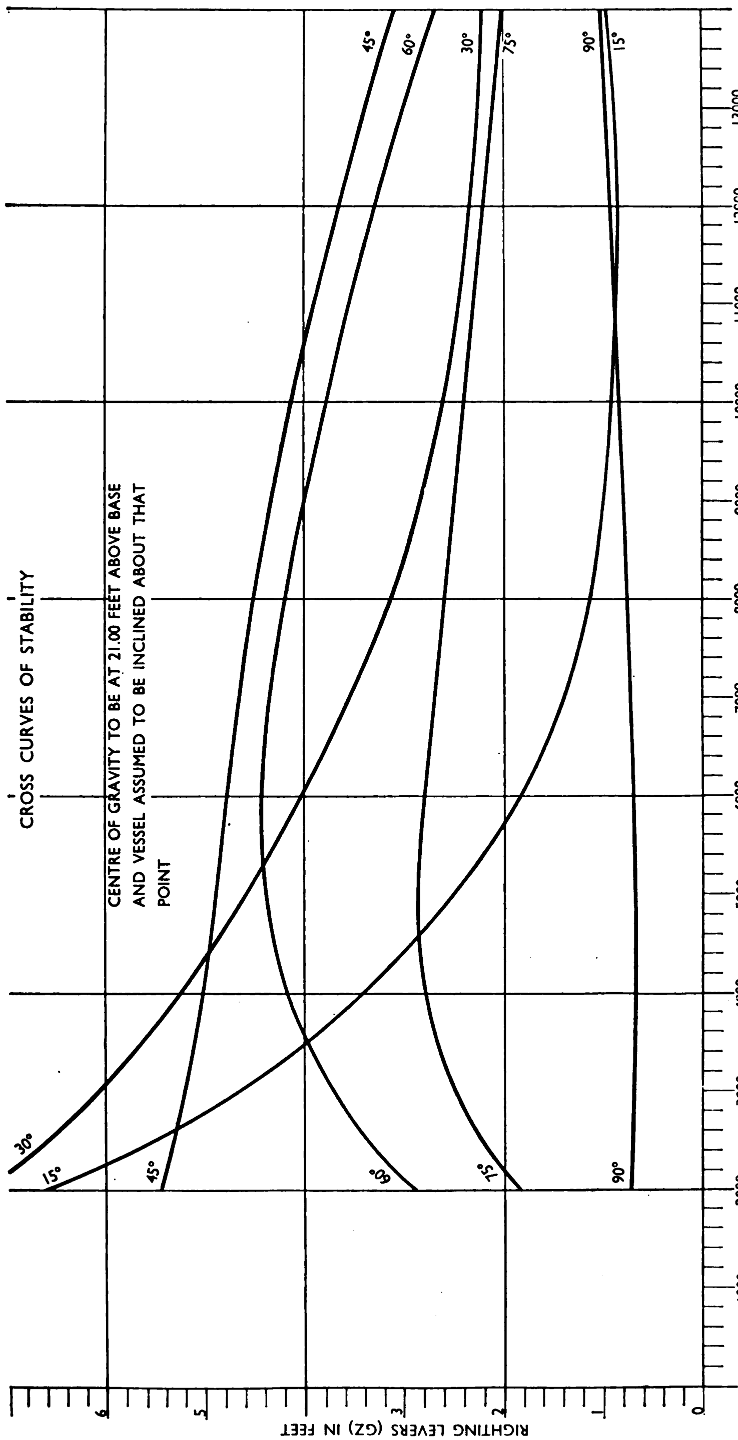


FIG. 1–3. Typical example of combined cross curves of stability

moment, because under these conditions the righting moment must balance the heeling moment. These conditions are only theoretical, however, because it is assumed that the sea is calm and there is no wind. Actually, when a ship is inclined to her angle of maximum stability by a steady heeling force, set up by a wind or asymmetrical flooding, for example, a slight increase in the force or a slight movement of the ship may cause her to capsize. The angle of maximum righting moment must not therefore be regarded as an angle at which the ship is safe under the influence of a steady heeling force; it represents, in still water, the angle at which the ship has no further margin of stability against capsizing.

Rolling in still water

What is meant by the *period of roll* of a ship is described in Chapter 15. The period depends on the degree of transverse stability of the ship in any one condition of loading, and also upon the disposition of weights about her longitudinal centre-line: but for any one condition the period of roll of a ship within small angles (of, say, from 10° to 15°) each side will be the same irrespective of the angles to which she rolls; in other words, her periods for rolls of, say, 10° and 5° will be the same for any one condition of loading. For large angles of roll the period increases with the angle of roll because of the change of metacentric height at large angles of heel.

The period of roll is inversely proportional to the righting moment. It is also affected by the disposition of weights in the ship. Two ships may have the same displacement and *GM* (i.e. equal righting moments), but if significant amounts of weight are placed at the ship's sides in one and concentrated at the centre line in the other, the former will have a greater period of roll than the latter because of the greater moments of inertia.

If there were no resistance to rolling, the motion would continue indefinitely. Resistance to rolling in *still* water is caused by:

surface disturbance, i.e. resistance caused by the actual displacement of water close to the ship by the movement of her hull from side to side;

eddy resistance caused by flat parts of the hull or projections such as rudder and bilge keels; and

frictional resistance between the water and the hull surface.

Of these, the first is the greatest; the second about one-fifth of this; and the last so small that it can be ignored.

In general, the resistance of the water tends not only to reduce the roll of a ship (the more violent the roll, the greater the resistance), but also to increase the moment of inertia and so increase the period of roll. The effect is greater when the ship is under way and increases with increasing speed.

Rolling in a seaway

The relationship between the period of roll and period of encounter with the waves is described in Chapter 15. From the seaman's point of view the most important lesson is to realise that, in a beam sea, if the period of roll is synchronous with the period of encounter a dangerous situation can arise. If the rolling is excessive, particularly in a ship with a small *GM*, and she appears reluctant to recover at the end of a roll, her course should be altered to break the synchronisation between the waves and the period of roll.

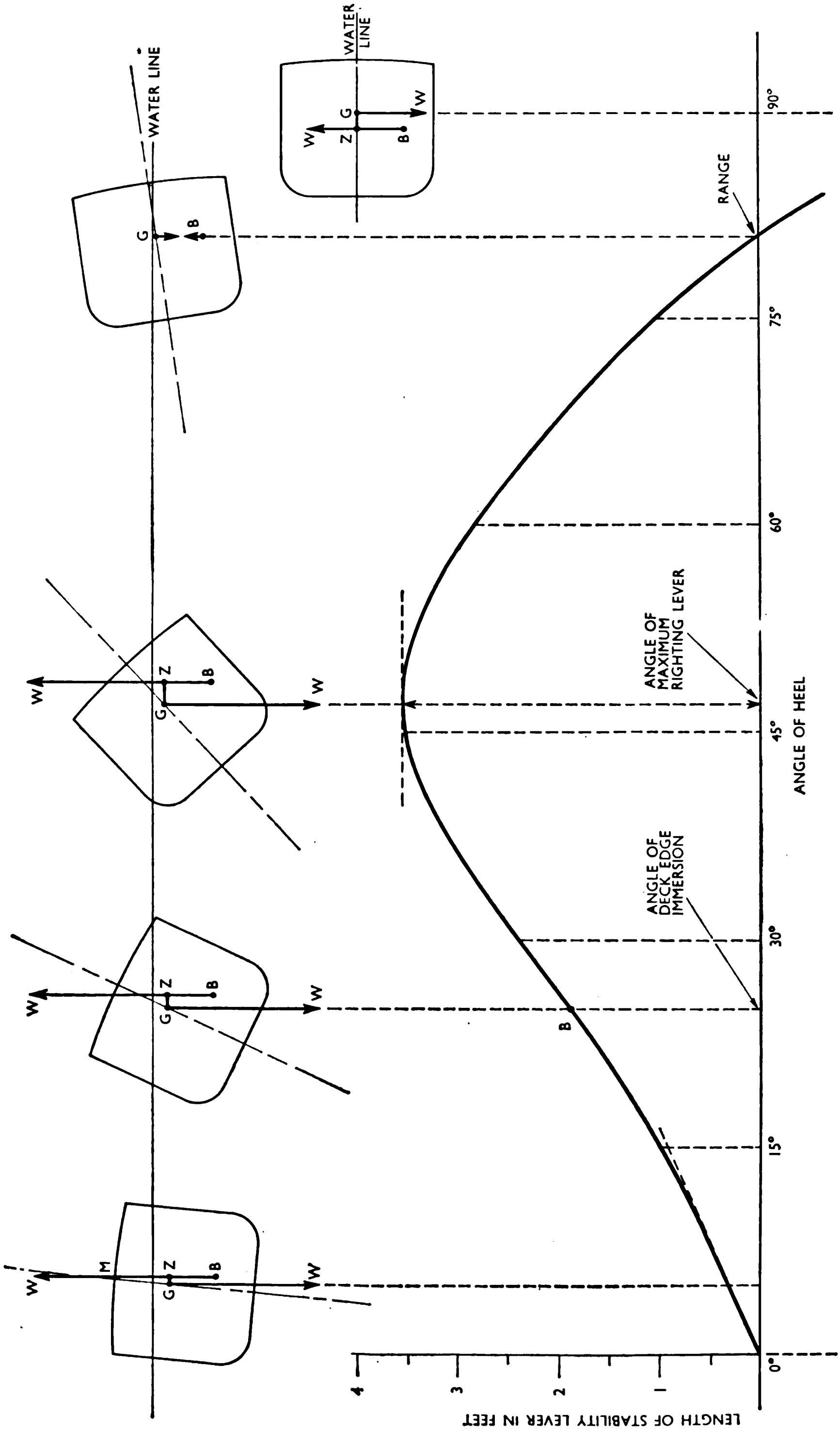


FIG. 1–4. A typical stability curve, showing the length of the righting lever for various angles of heel

If the period of roll is large in comparison with the period of encounter the ship will probably roll only slightly and with the same period as in still water. Passenger ships are usually designed to have small transverse metacentric heights and long periods of roll, so that they have this quality of being steady in a beam sea. Such ships will roll independently of the waves, which will probably break against their sides, but without much inconvenience because passenger ships normally have a high freeboard.

Inclining experiment

When a ship is built, or has undergone considerable reconstruction, an *inclining experiment* is carried out to determine whether the actual position of her centre of gravity for a specified condition of loading coincides with the designer's calculated position. When the actual position of the centre of gravity for one condition of loading has been determined by experiment it is a comparatively simple matter to calculate its position accurately for any other condition of loading.

The inclining experiment is usually carried out with the ship's feed-water tanks, fresh-water tanks, ballast tanks, fuel tanks or bunkers either empty or full and pressed up, and with her stores on board but without any ammunition or cargo. The experiment is conducted in still water, preferably in a dock or basin, and on a calm day. If there is any wind the ship should be placed head to wind. All her machinery is stopped, her pumping systems are drained and the bilges cleared, and, with the exception of those men required for the experiment, her crew are landed.

Long pendulums, about 15 ft in length, are rigged through suitable hatchways or in the holds, usually one forward and one aft, to measure the angle of inclination; and a known weight of ballast, sufficient to incline the ship 2° to 3°, is placed on the upper deck and symmetrically disposed about the fore-and-aft centre-line. The ship should then be floating absolutely upright.

The weights are then shifted a measured distance across the upper deck, and when the ship is at a steady angle of heel her inclination is measured by means of the pendulums. The weights are then brought back to their original positions, and the ship should then regain her upright position. The weights are then shifted to the same distance from the ship's centre-line on her opposite side, and her angle of inclination to that side is measured.

The displacement of the ship is obtained by comparing the mean of her draughts forward and aft with her displacement curve, and from this information the metacentric height GM can be calculated from the formula:

$$GM = \frac{w \times d}{W \times \tan \theta}$$

where:

w is the sum of the known weights;

d is the distance they have been moved across the ship;

W is the displacement of the ship, including the weight of ballast w; and

θ is the mean angle of inclination.

The distance of the metacentre above the keel for this particular condition of loading is obtained from the metacentric diagram, and so the exact position of the centre of gravity can be determined.

METHODS OF IMPROVING TRANSVERSE STABILITY

The transverse stability of a ship can be improved structurally by increasing the ratio of her beam to her draught, which will result in raising the position of her metacentre and thus increasing her metacentric height. A ship's stability at large angles of heel can be improved by increasing her freeboard, provided that the additional structure does not unduly raise her centre of gravity and so reduce her metacentric height. Transverse stability can also be improved by adding ballast low down in the ship or by removing topweight from her; both methods will result in lowering her centre of gravity and so increasing her metacentric height, but whereas the former will increase her draught and reduce her freeboard, the latter will have the opposite effect. Free-surface liquid—that is, liquid which is free to move from side to side of a partially-filled tank or compartment—will result in reducing the metacentric height.

Ballasting and removal of topweight (fig. 1–5)

Many cargo vessels are very tender in the light load condition, or *flying light*, and some may then even have a negative metacentric height. To offset this tenderness they may carry *dead* ballast in the form of shingle or pig-iron at the bottom of their holds, or they may be provided with specially constructed, rapidly floodable ballast tanks built into their double bottoms. The dead ballast may be carried temporarily or permanently, and in some ships both water and dead ballast are used.

The effect of ballasting is to lower the centre of gravity without materially affecting the position of the metacentre, thus increasing the metacentric height. The amount by which the centre of gravity is lowered is given by the formula $\frac{w \times h}{W+w}$, where w is the weight of the ballast, h is its distance below the original centre of gravity, and W is the original displacement of the ship. Another effect of ballasting, which may be disadvantageous, is to increase the draught of the ship.

Removal of topweight, like ballasting, lowers the centre of gravity, but as it also decreases the draught of the ship, it may be preferable to ballasting in ships in which an increase of draught would be a disadvantage. The amount by which the centre of gravity is lowered by the removal of topweight is given by the formula $\frac{w \times h}{W-w}$, where w is the topweight, h is its height above the original centre of gravity, and W is the original displacement of the ship.

It is a common mistake to suppose that a ship is made steady by ballasting or the removal of topweight. Steadiness is obtained by having a small metacentric height; the metacentric height is increased by ballasting or removing topweight and the ship is made stiffer and therefore more lively. In this connection it is of interest to recall that in the last century many of the old 64-gun ships were converted to 38-gun frigates (or *razées*, as they were then called) by removing the upper deck together with its guns and topsides and fitting lighter masts and yards. The removal of this topweight considerably increased the metacentric height, and the ships rolled so violently that they often sprang their topmasts. This failing was overcome to a certain extent by increasing the size, and therefore

the weight, of the masts and yards, thus decreasing the metacentric height by adding topweight.

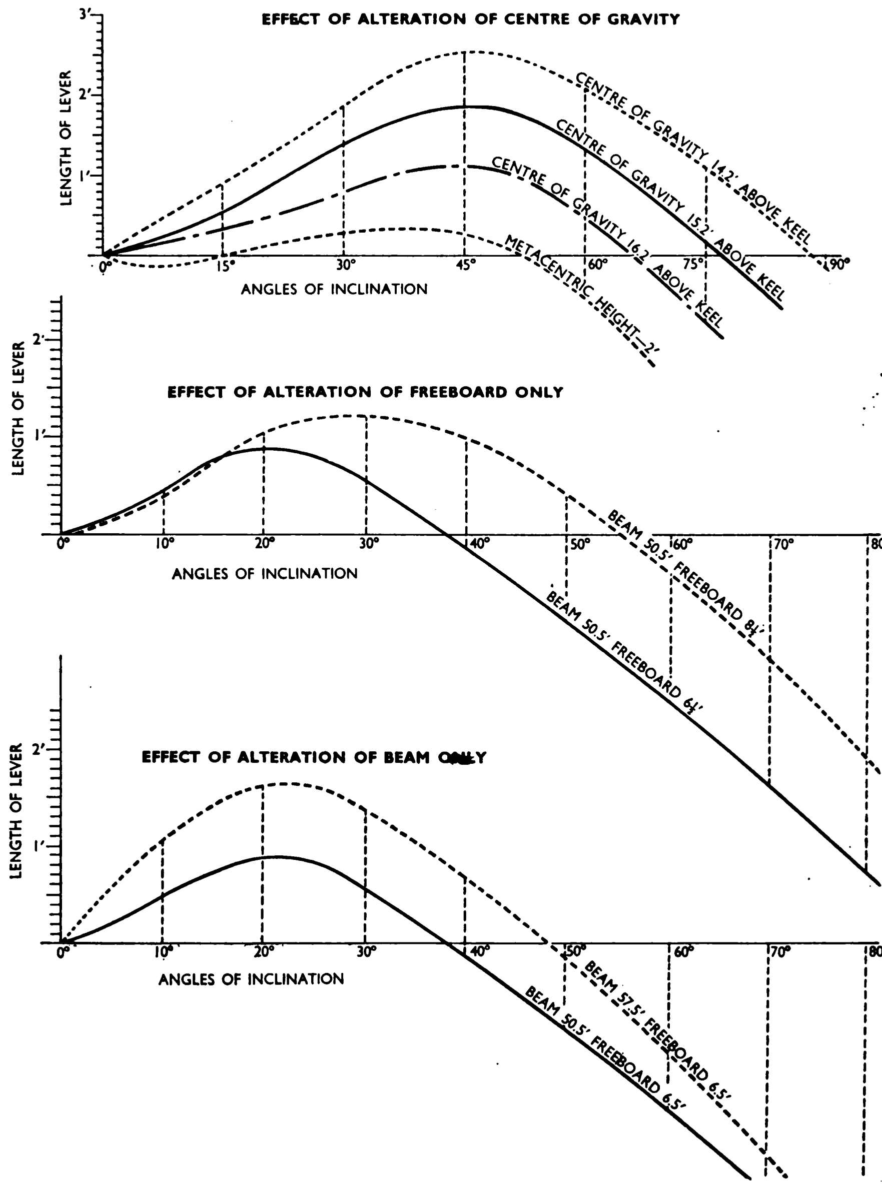


Fig. 1–5. Curves of stability, showing effect of altering centre of gravity, beam and freeboard

An opposite effect to that of ballasting arises from the consumption of fuel, water and stores if they are stowed below the ship's centre of gravity. This is particularly evident in the case of oil fuel, because the fuel tanks of most oil-

burning ships are built into their double bottoms, and the effect of using up the oil fuel is then the same as that of removing ballast. Consuming much of the ship's fuel can seriously reduce her margin of stability unless it is countered by ballasting, or anticipated by the disposition of the cargo. In the early years of this century a cargo vessel was provided with little information about her stability, her loading being left to the judgment and experience of her master. This lack of information sometimes led to dangerous situations in which a ship, though perfectly stable on sailing, was in a precarious state on arrival at her destinatian because of her loss of stability through the consumption of fuel and water during the voyage. Notable examples were the Baltic traders when carrying deck cargoes of timber, which often arrived in this country with negative stability and an alarming heel.

When a cargo ship is lightly laden her waterplane area may be reduced considerably by a small reduction of draught, and consequently the position of her metacentre may then be lowered appreciably. When lightly laden the adverse effect of this lowering of the metacentric height must be considered in conjunction with the adverse effect of the rise of the centre of gravity due to the consumption of fuel. In a typical cargo vessel of some 10,000 tons, her centre of gravity may rise as much as six inches during a voyage while her metacentre may fall by two inches, making a total reduction of some eight inches in her metacentric height.

Increasing the freeboard

The weight of the structure involved by increasing the freeboard of a ship will result in raising her centre of gravity, and because her draught and displacement will be increased by a small amount her metacentre will be lowered slightly. The immediate result will therefore be to decrease slightly her metacentric height and therefore her initial stability, but at large angles of heel the result will be to increase her righting moment, the angle of her deck-edge immersion, and her range of stability.

Girdling

Girdling means increasing a ship's beam with the object of increasing her metacentric height. In recent years it has been necessary to improve the stability of a large ship after modernisation, and a *bulge* was added outside the main hull at about waterline level.

In the days of sail one of the chief tactical considerations in an action was to gain the weather gauge, so that the final approach to the enemy could be made from windward and his freedom of manœuvre thereby restricted. This necessitated fighting the lee guns, and ships of the line had to be stiff enough to resist being heeled by a beam wind sufficiently to submerge the ports of their lowest tier of guns. Moreover, the maximum angle of elevation of these guns was only 12° and therefore, with her crew manning the guns on the lee side, the heel of the ship to leeward had to be limited to 12°. In practice the designers of those days limited the heel to 7° in a 'topsail wind', which corresponded to a wind pressure of 2 lb per sq. ft.

Towards the end of the 17th century the stability of ships of the line was unfavourably criticised by our seamen, and our ship designers were then faced

with a difficult problem, because removal of topweight would impair the ship's fighting efficiency, and ballasting would increase her draught and reduce the freeboard of her lower gun-ports. In the event they resorted to girdling, which consisted of fitting a wooden belt, from 12 to 18 inches thick, around the ship at her waterline and extending three or four feet above and below it. This virtually increased the beam of the ship and so raised the position of her metacentre without materially altering her draught or the position of her centre of gravity. The rise of the metacentre was roughly equivalent to the thickness of the girdling, or half the increase of beam. An added advantage of the girdling was that it provided what was virtually an armour belt at that most vulnerable part of the ship—'between wind and water'.

Effect of free-surface liquids

When a tank is *slack*, i.e. when it contains some liquid but is not full, the metacentric height is reduced by an amount depending solely on the extent of the free-surface of the liquid and its density relative to that of sea water. A few inches of liquid in the bottom of a rectangular tank would therefore reduce the metacentric height by as much as would several feet, and it is therefore important to ensure that ballast tanks are either pressed up or completely drained.

The loss of metacentric height due to free-surface is given by the formula $\frac{Di}{V}$, where D is the relative density of the liquid compared with the water in which the ship is floating, i is the moment of inertia of the free-surface about the longitudinal axis through the centre of its area, and V is the volume of displacement of the ship. The moment of inertia of the free-surface of a liquid in a rectangular tank is given by the formula $\frac{L \times B^3}{12}$, where L and B are the length and breadth respectively of the tank.

It will therefore be seen that if a tank is divided by a longitudinal partition into two equal parts, the loss of metacentric height due to free-surface effect will be reduced to a quarter of that of the undivided tank. The deep tanks of cargo ships, and any large tanks which extend athwartships, are therefore divided by one or more longitudinal partitions or baffle-plates.

Pressing up a tank or completely draining it will therefore make a ship more stable, but it must be emphasised here that any attempt to improve a ship's stability while at sea must be done with great caution. Pumping, flooding and draining operations take some time to carry out, and in the process the free-surface effects of the slack tanks may well cancel a margin of stability, particularly if it is small and the tanks are large. Many losses of ships have been attributed to attempts to improve their stability by pumping, flooding or draining while the ship was in a seaway.

A certain amount of ullage has to be left in fuel tanks when filling them, to allow for the expansion of the oil with any rise in its temperature, and in oil tankers this results in a considerable reduction of the metacentric height due to free-surface effects, even though the ships are designed with a high degree of compartmentation and each tank is usually divided into three parts by longi-

tudinal bulkheads. To compensate for this adverse effect tankers are provided with a considerable margin of stability by giving them a larger ratio of beam to draught than is usually given to vessels designed for carrying a general cargo.

Another danger is that of free water on the decks, particularly in cargo vessels of the three-island type whose forward and after well-decks are enclosed by high bulwarks. Such ships are fitted with large *freeing ports* to allow any water shipped in a seaway to drain quickly over the sides. If this were not done the effect of the free-surface water, combined with the loss of metacentric height due to the added weight of the water at so high a level, might seriously reduce the ship's margin of stability. Unfortunately, a vessel may also ship water through her freeing ports, and it is not unknown for the flaps of the freeing ports to be secured for the sake of comfort, thus endangering her should she ship a very heavy sea.

Free communication

When a ship is heeled, free surface in a compartment in free communication with another will extend across the breadth of both compartments. When an off-centre compartment is holed and open to the sea, the initial weight of flooding is progressively increased as the ship heels towards the damage. It is important therefore that valves, etc. which give access between compartments or to the sea are closed when not in use, to prevent large movements of liquid as the ship heels.

Bulk cargoes

A bulk cargo, such as grain, can produce an effect similar to that of free-surface liquids, but modified by the inertia of the individual particles and the friction between them. For example, a heavy roll to one side may shift the cargo, but it will not necessarily shift back with a roll to the opposite side. Bulk cargo ships are therefore fitted with permanent, or temporary, centre-line bulkheads in their holds, and these may be supplemented by *shifting boards* further to subdivide the cargo and prevent it from shifting. In addition, the cargo is pressed up to the tops of the holds and between the deck head beams, special feeder-trunks being provided over each hold for this purpose. When a hold cannot be pressed up because of lack of grain, a certain proportion of the grain must be bagged and laid on platforms over the bulk grain; the bagged grain will have little tendency to shift and by its weight will tend to prevent the bulk grain shifting.

Ships built for carrying bulk cargoes are usually designed with a higher margin of stability than those designed for carrying general cargoes, for the following reason. The centre of gravity of a bulk cargo is unalterable and lies at the centre of its volume, and when the ship is fully loaded she will therefore have a high centre of gravity; with a general cargo the position of the ship's centre of gravity can be kept reasonably low by stowing the heavier kinds of cargo in the lower holds.

HOISTING OUT A HEAVY WEIGHT

The angle to which a ship will be heeled when hoisting out a heavy weight by one of her derricks is given by the formula:

$$\tan \theta = \frac{w \times d}{W \times GM},$$

where:

θ is the angle of heel;

w is the weight in tons to be hoisted out;

d is the horizontal distance in feet between the stowage position of the weight and its position when slung outboard from the derrick head;

W is the displacement of the ship; and

GM is her metacentric height in feet.

When hoisting a heavy weight in or out by a derrick make sure that the ship has a sufficient margin of initial stability, because as soon as the weight is slung its effect will act through the head of the derrick, thus increasing considerably the height of the centre of gravity of the ship and reducing her metacentric height correspondingly. Moreover, when the weight is slung outboard, the further the ship heels the greater will be the heeling moment of the weight, and measures must therefore be taken to ensure that the ship remains as upright as possible throughout the operation. Ships which may have to deal with heavy lifts are provided with special ballasting arrangements to ensure the necessary degree of stability and resistance to heeling when hoisting the weights in and out. Always work the derrick slowly, and as smoothly and steadily as possible.

LONGITUDINAL STABILITY AND TRIM

Longitudinal metacentre

The longitudinal metacentre M_L of a ship is found in a similar manner to that in which her transverse metacentre is found. In fig. 1–6 the ship is assumed

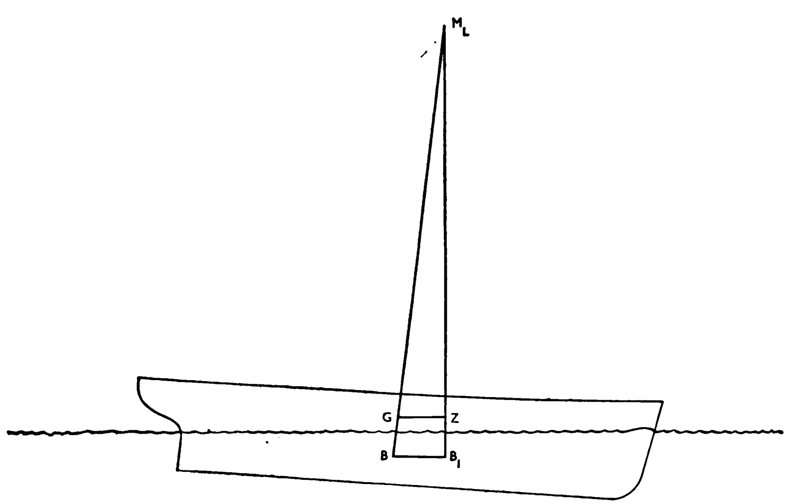


FIG. 1–6. Longitudinal metacentre

to have been tipped forward by some external force so that the longitudinal centre of buoyancy (*LCB*) has moved forward to B_1, thus producing a longitudinal righting moment, $W \times GZ$.

The height of the longitudinal metacentre above the centre of buoyancy of an average ship is given very roughly by the formula $BM = \frac{L^2}{12D}$, where L is the length of the ship and D her draught. It will therefore be seen that a ship is far stiffer longitudinally than transversely.

Longitudinal centres of buoyancy and gravity

When a ship is steady her *LCB* will lie at a position a little before or abaft amidships, and its position will change as the draught of the ship is changed. Under the same conditions a ship's longitudinal centre of gravity (*LCG*) lies directly above her longitudinal centre of buoyancy.

Centre of flotation (CF) or tipping centre (TC)

When a ship is steady her *centre of flotation*, or *tipping centre*, lies at the centre of her waterplane area, and it is about a transverse axis through this point that the ship trims. If a weight is added to a ship directly above her centre of flotation she will sink bodily and on an even keel, but if added before or abaft her centre of flotation the ship will trim by the head or the stern, respectively, as well as sink bodily. Like the longitudinal centre of buoyancy, a ship's centre of flotation lies at a position a little before or abaft amidships, and its position will change if the draught of the ship is changed. If the draught of a ship is increased without changing her trim her longitudinal centre of buoyancy and her centre of flotation will usually move aft, the latter more so than the former. Both will also change position with any change of trim because this will change the waterplane area. In a warship the centres of buoyancy and flotation are usually abaft amidships.

Tons-per-inch-immersion (TPI)

This is the weight required to increase the mean draught of a ship by one inch, and it is assumed that it is placed directly above the centre of flotation or disposed symmetrically before and abaft it. The weight required will change with a change of waterplane area and therefore with a change of draught, and for any particular draught it can be found from the following formula:

TPI = the increase in displacement due to a uniform increase in the draught of one inch

$$= \frac{1}{35}\left[\frac{A \times 1}{12}\right] = \frac{A}{420} \text{ tons,}$$

where A is the waterplane area for a particular draught in square feet.

Trim and change of trim

Trim is the inclination of a ship in a fore-and-aft sense, and it is usually measured by the difference between her draughts forward and aft. If the draughts are the same the ship has no trim and she is said to float on an *even keel*; if the draught forward is the greater she is said to trim *by the head*, and if the draught aft is the greater she is said to trim *by the stern*.

Change of trim is a change in the difference between the draught forward and the draught aft caused either by shifting weights forward or aft, or by adding or removing weights before or abaft the ship's centre of flotation. If a weight is moved forward or aft there will be no change in the ship's displacement or mean draught, and she is then assumed to incline about the transverse axis through the centre of flotation corresponding to her displacement. If a weight is added or removed, however, her displacement and draught will be altered; and, provided the change of draught is not great, the ship can be assumed to trim about the transverse axis through the centre of flotation corresponding to her new displacement and draught.

When weights are shifted, added or removed, the positions of the centres of gravity, buoyancy and flotation will change in relation both to the ship and to themselves; the waterplane area will also be changed. But, unless the changes of weight are very considerable, the relative changes of position of the various centres will be very little, and in practice they are disregarded unless very accurate estimations are required.

The total change of trim is divided between the ends of the ship in the ratio of their distances from the centre of flotation. For rough calculations the draughts forward and aft may be assumed to change by half this change of trim. If, for example, the total change of trim is two inches by the head, it is assumed that the draught forward will be increased by one inch and the draught aft will be decreased by one inch.

Moment to change trim one inch (M.C.T.1″)

This moment depends on the displacement of the ship, her length and her longitudinal metacentric height; it will therefore vary with her condition of loading and is expressed in tons feet. The relationship between these factors is shown by the formula:

$$M.C.T.1'' = \frac{W \times GM_L}{12 \times L},$$

where:

$M.C.T.1''$ is the moment to change trim by one inch;

W is the displacement of the ship in tons;

GM_L is the longitudinal metacentric height in feet; and

L is the length of the ship.

The change of trim caused by shifting a weight forward or aft can be found from the formula:

$$\text{change of trim} = \frac{w \times d}{M.C.T.1''}$$

where:

w is the weight in tons;

d is the distance in feet the weight has been shifted; and

$M.C.T.1''$ is the moment to change trim one inch.

EXAMPLE

A ship with a displacement of 1,980 tons has a length of 220 ft between perpendiculars and a longitudinal metacentric height of 252 ft. Thirty tons of

oil fuel are pumped from one tank to another which lies 63 ft further forward. Before pumping was begun her draughts were 10 ft 6 in. forward and 11 ft 6 in. aft. Find her draughts after pumping is completed.

$$\text{M.C.T.}1'' = \frac{1980 \times 252}{12 \times 220} = 189 \text{ tons ft.}$$

$$\text{Total change of trim} = \frac{30 \times 63}{189} = 10 \text{ in. by the head.}$$

Therefore the new draughts will be:

forward 10 ft 11 in.
aft 11 ft 1 in.

If a weight is added before or abaft the centre of flotation the change of trim is found by assuming that the weight was first added directly above the centre of flotation and then shifted forward or aft to its position.

Example

The ship in the foregoing example in her original condition has a tons-per-inch-immersion of 9. A weight of 27 tons is then placed in her No. 2 hold at a distance of 42 ft before her centre of flotation. Find her new draughts.

$$\text{Mean sinkage} = \frac{27}{9} = 3 \text{ in.}$$

in which condition the draughts would be:

forward 10 ft 9 in.
aft 11 ft 9 in.

$$\text{Total change of trim} = \frac{27 \times 42}{189} = 6 \text{ in. by the head.}$$

The new draughts will therefore be:

forward 11 ft
aft 11 ft 6 in.

If a weight is removed from a position before or abaft the centre of flotation the change of trim is found by assuming that the weight was first shifted to the centre of flotation and then removed.

Example

A ship is about to discharge cargo as follows: 20 and 45 tons at 105 and 80 ft, respectively, before her centre of flotation, and 30 and 22½ tons at 60 and 80 ft, respectively, abaft it. Her draughts are 20 ft forward and 22 ft aft, in which condition her tons-per-inch-immersion is 29 and her moment to change trim one inch is 600 tons ft. Find her draught after she has discharged her cargo.

The change of trim is first found by multiplying each weight by its distance from the centre of flotation, finding the sum totals of moments before and

abaft the centre of flotation, then substracting the lesser amount from the greater and finally dividing the result by the moment to change trim one inch. Thus:

$$\frac{(20\times 105+45\times 80)-(30\times 60+22\tfrac{1}{2}\times 80)}{600}\text{ in.}$$

$$=\frac{2100}{600}=3\tfrac{1}{2}\text{ in.}$$

The change of trim will be by the stern, because the sum of the total moments before the centre of flotation is greater than that abaft it.

The draughts will therefore be approximately:

forward 19 ft $10\frac{1}{4}$ in.
aft 22 ft $1\frac{3}{4}$ in.

The decrease of draught is then found by dividing the sum of the weights by the tons-per-inch-immersion, thus:

$$\frac{20+45+30+22\tfrac{1}{2}}{29}=4\text{ in. (approx.)}$$

The ship's draughts after discharging cargo will therefore be:

forward 19 ft $6\frac{1}{4}$ in.
aft 21 ft $9\frac{3}{4}$ in.

Change of draught when passing from salt water to fresh water

The draught of a ship passing from salt water to fresh water will increase, because salt water is denser than fresh water. The increase is usually small and can be calculated from the formula:

$$S=\frac{W}{T}\left[\frac{d_s-d_f}{d_f}\right]$$

where:

S is the sinkage, in inches;

W is the displacement, in tons;

T is the tons-per-inch-immersion in salt water;

d_s is the density of salt water, in lb/ft^3;

d_f is the density of fresh water, in lb/ft^3.

d_s and d_f are approximately 64 and 63 lb/ft^3, respectively, so that the formula may be written in the simpler form:

$$S=\frac{W}{63T}$$

The estimation of this change of draught is important for a sea-going ship when loading her cargo some miles up a river, because when loading to her marks it determines to what extent the ship can be immersed above her appropriate load line and still conform to *The Load Line Rules* (as described in Chapter 3) when she reaches the sea.

In practice cargo ships are assigned a *fresh-water allowance*, which represents the change in inches of the mean draught of the ship in her deep load condition when she passes from salt to fresh water or *vice versa*. At river mouths, however, the water is neither entirely fresh nor entirely salt; and, when estimating the

change of mean draught, allowance must be made for the different densities of the river water, salt water and fresh water. This is done by finding, by means of a hydrometer, the density of the river water at the place where the ship is lying and then calculating the change of mean draught by means of the formula:

$$C=\frac{A\times d}{D},$$

where:

C is the change of mean draught when passing from the river to the sea;

A is the fresh-water allowance assigned to the ship;

d is the difference in density between sea water and the river water; and

D is the difference in density between salt water and fresh water.

Example

The density of the water at a certain river port is 1,008 oz per cu. ft. To what extent can an outward-bound ship with a fresh-water allowance of 6 in. be immersed below her load line? Assuming that the density of fresh water is 1,000 oz per cu. ft and the density of the sea water off shore is 1,025 oz per cu. ft, the change of mean draught will be:

$$\frac{6\times(1025-1008)}{1025-1000}=\frac{6\times 17}{25}=4 \text{ in. (approx.)}$$

EFFECTS OF LOADING AND TRIM

When loading a vessel one must see that she is so trimmed that she will handle well both in a seaway and in narrow waters, and that she has sufficient buoyancy at bows and stern to ride the seas; and one must avoid any concentrations of weight which may place undue stresses on her structure.

Handling qualities

Any ship which is trimmed at all by the bows will probably be difficult to handle both in a seaway and in narrow waters, because her pivoting point will then be shifted well forward and so will reduce the effect of her rudder. Most ships handle best when trimmed a little by the stern, and when flying light this trim is usually increased to ensure that the propeller and rudder are sufficiently immersed.

The trim of a cargo vessel with her machinery amidships is much easier to estimate and control than that of a vessel with her machinery aft, because in the former vessel the permanent weight is at her tipping centre and will exert little moment before or abaft it, whereas in the latter vessel, which has her permanent weight right aft, it is difficult to estimate the changing effect of its moment about the tipping centre as cargo is loaded into the holds. In such vessels the danger lies in loading her down to her marks and then finding her trimmed by the head, when nothing can be done to correct it except reloading the cargo, because by flooding the after ballast tanks the ship will be brought below her marks. To guard against this it is common practice to fill the forepeak tank or No. 1 ballast tank before loading, thus enabling any trim by the head to be corrected by pumping out these tanks.

Pitching

Any concentration of weight forward in a ship will reduce the buoyancy and increase the moment of inertia of her bows, which will result in the ship being sluggish by the head and failing to rise to the seas. She will be liable to ship heavy seas when steaming head to sea, which may not only strain her structure but also stave in her hatches. Any concentration of weight forward and aft will increase the moment of inertia of the ends of the ship and so increase the stresses of hogging, and may result in her breaking her back.

While a concentration of weights amidships will ensure that the bows and stern are buoyant it will increase the stresses of sagging, and the resultant lively pitching may also strain the ship's structure.

A rough compromise between these two extremes is to put 60 per cent of the total weight of cargo in the midship holds, and distribute the remainder between the forward and after holds. The distribution of the cargo by volume, and therefore to a certain extent by weight, is of course governed by the shape of the ship, because the taper at bows and stern makes the forward and after holds much smaller than the midship holds.

Shearing stresses

Because of the subdivision of a cargo vessel into several large spaces for the accommodation of her cargo and machinery, her hull is more subject to the stresses of shearing at the main transverse bulkheads than are the hulls of warships and liners, which have a far greater degree of subdivision. To minimise these stresses the heavier cargo should be placed in the main holds and the lighter cargo in the forward and after holds.

Summary

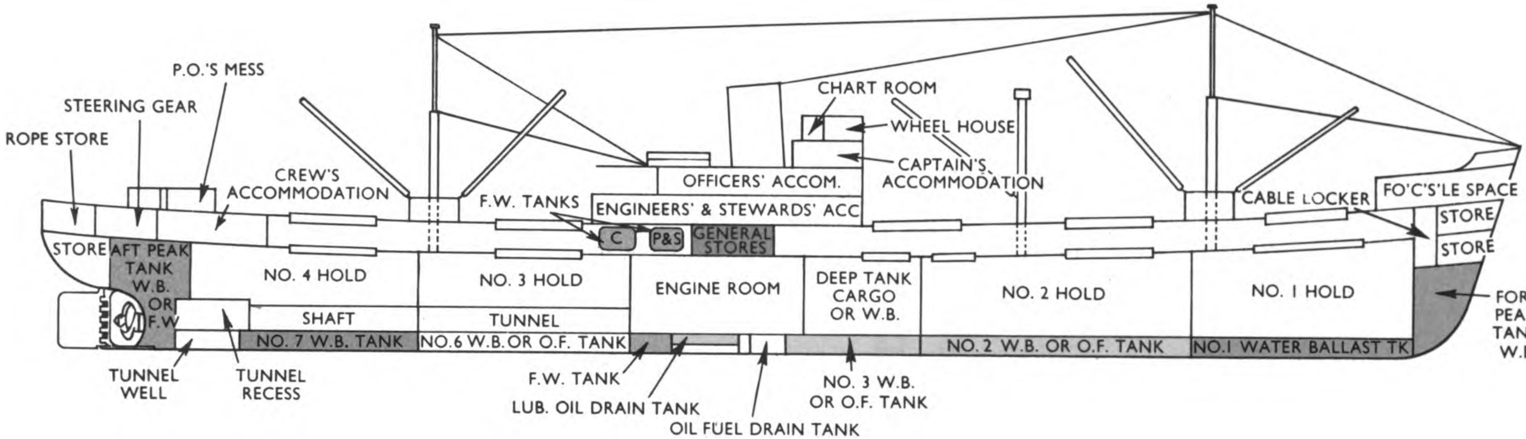
The trim of a ship should be arranged so that she floats on an even keel or is trimmed a little by the stern; she should never be trimmed by the head. The cargo should be distributed symmetrically before and abaft the ship's tipping centre, and the greater part of its weight should be amidships to ensure that her bows are buoyant and that she is stiff longitudinally, and to avoid exceptional shearing stresses at her main transverse bulkheads.

STABILITY PROBLEMS IN WARSHIPS AND CARGO SHIPS

Stability problems in a warship are very different from those arising in a cargo ship. A warship's officers are not greatly concerned with loading problems because the stowage of ammunition, fuel and stores is fixed in the design of the ship. The difference between deep and light load conditions is relatively small; and the manner in which fuel tanks must be emptied, and any necessary ballasting done, is detailed by the designer. Provided the designer's instructions are followed, the embarkation, disembarkation or consumption of fuel, stores and ammunition will not affect greatly the ship's stability. However, the ship's officers must be capable of dealing quickly and effectively with the threat to stability and buoyancy caused by an inrush of water, if the ship is damaged below the waterline by, for example, a torpedo or mine.

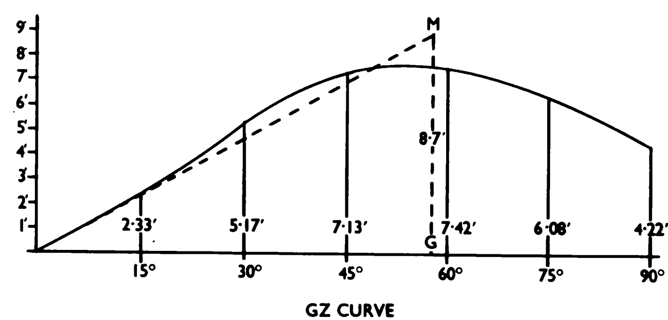
The officers of a cargo ship, on the other hand, must see that the cargo is

A COMPARISON BETWEEN STABILITY CURVES FOR A CARGO SHIP IN DIFFERENT CONDITIONS



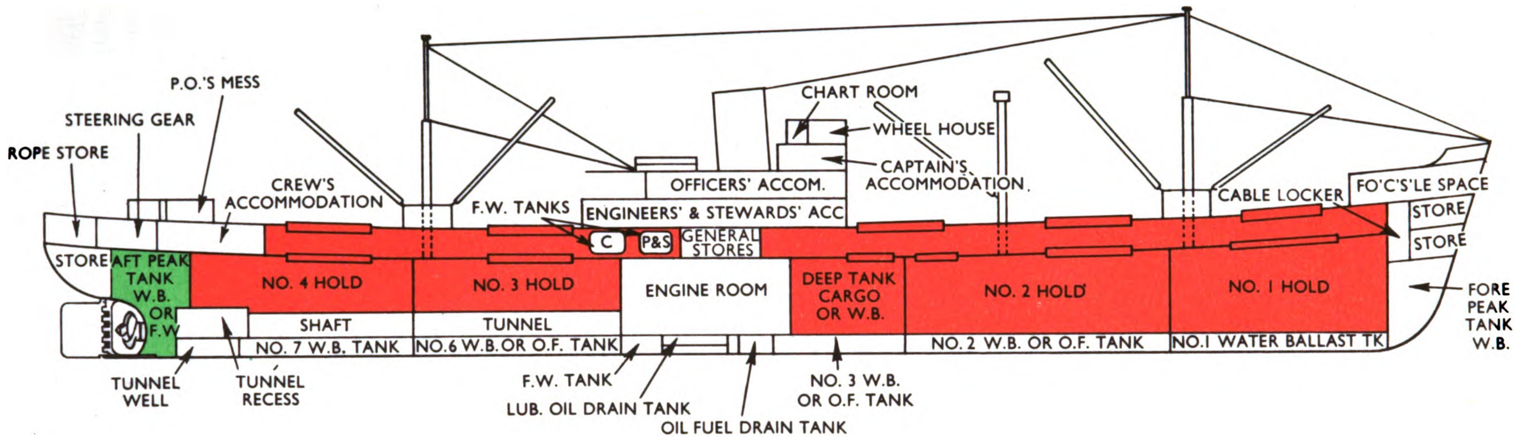
CONDITION - BALLAST DEPARTURE

	LIGHT SHIP	3,774 TONS
▭	OIL FUEL	944 TONS
■	FRESH WATER	234 TONS
■	FEED WATER	58 TONS
■	WATER BALLAST	1,991 TONS
▭	LUB. OIL	6 TONS
■	STORES	20 TONS
	DISPLACEMENT	7,027 TONS



C.G. ABOVE BASE	17·54 FT
METACENTRE ABOVE BASE	26·24 FT
G.M. PLUS	8·7 FT
DRAUGHT FORWARD	12' 5½"
DRAUGHT AFT	16' 3½"
MEAN DRAUGHT	14' 4½"

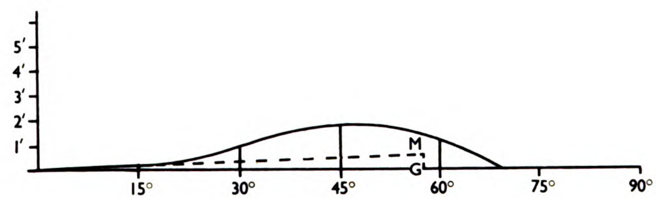
Fig. 1–7. A typical stability curve for a cargo ship in the condition of *ballast departure*



CONDITION - LOADED ARRIVAL

LIGHT SHIP	3,774 TONS
AFT PEAK TANK, S.W.	200 TONS
HOMOGENEOUS CARGO OF GRAIN	
STOWED AT 71·2 CU. FT PER TON	8,138 TONS
DISPLACEMENT	12,112 TONS

C.G. ABOVE BASE	23·59 FT
METACENTRE ABOVE BASE	23·89 FT
G.M. PLUS	0·3 FT
DRAUGHT FORWARD	22′ 8¼″
DRAUGHT AFT	23′ 11¼″
MEAN DRAUGHT	23′ 3¾″



GZ CURVE

Fig. 1–8. A typical stability curve for a cargo ship in the condition of *loaded arrival*

loaded so as to ensure that their ship will have a reasonable margin of stability throughout a voyage, that she will handle well, and that any loss of stability from the consumption of fuel and stores can be countered if necessary by ballasting. Their problem, though important, is not urgent, and they can usually devote time to it. Should their ship be damaged below the waterline there is little that can be done to regain any lost buoyancy or stability. Because of the large spaces into which a cargo ship is divided, and the lack of watertight subdivision, pumping or counter-flooding are of little avail. Probably the most that can be done is to strengthen the bulkheads by shoring them to prevent the flood water from spreading to other parts of the ship.

STABILITY DATA FOR A CARGO SHIP

There is unfortunately no standard method of preparing stability information for the use of ships' officers. It may be in the form of graphs or tables or both, and differences occur in each method. Generally speaking, however, the same kind of information is given for each ship, and the following is typical of the stability data provided for a cargo vessel.

Cross curves of stability

A typical graph of cross curves of stability is illustrated in fig. 1–3. The curves, each of which represents a certain angle of heel, are plotted on a horizontal axis of displacement and a vertical axis of the righting lever, and the graph is based on an arbitrarily selected position for the centre of gravity (in this case 21 ft above the keel). The graph gives the length of the righting lever in feet for any displacement at various angles of heel, always assuming that the centre of gravity remains at a height of 21 ft. From this graph the righting-lever, or *GZ*, curve for a particular condition of loading and for a particular height of the centre of gravity can be drawn if needed.

Righting-lever, or GZ, curves

These are drawn on a horizontal axis graduated in degrees to represent the various angles of heel for which the cross curves of stability have been drawn. The vertical axis represents in feet the length of the righting lever at the particular condition of loading for which the curve is drawn. The curve will therefore show at a glance the degree of stability of the ship throughout a range of heel from 0° to 90° for any particular condition of loading.

These curves are usually drawn by the designer for the following conditions of loading: *light ship*, i.e. with no water, fuel, stores or cargo on board; *ballast departure*, i.e. with fuel, stores, fresh and feed water on board, and with ballast tanks full, but with no cargo; *ballast arrival*, i.e. similar to ballast departure but with most of the fuel, fresh water and stores consumed; *loaded departure*, i.e. fully loaded with fuel, water and stores, and with all holds fully loaded with a homogeneous cargo; and *loaded arrival*, i.e. similar to loaded departure but with most of the fuel, fresh water and stores consumed. Two typical examples of stability curves are illustrated in figs. 1–7 and 1–8.

These are the extreme conditions of loading and from them the seaman can estimate at a glance the degree of stability of his ship through the range of

conditions in which she is liable to be loaded. *GZ* curves can be drawn for any particular condition of loading.

Hydrostatic curves

Those factors affecting the stability and trim of a ship which depend solely on the underwater form of the hull can be depicted in the form of curves on a graph based on the draught of the ship. Such curves are termed *hydrostatic curves* and typical examples are described below and illustrated in fig. 1–9. The horizontal axis of the graph is graduated in tons displacement, and the vertical axis, which is graduated in feet, represents the draught of the ship.

Displacement curve. This curve approximates to a straight line, and from it can be found the displacement of the ship in salt water for a given draught. A separate curve for fresh water is often given for ships which may navigate in rivers or inland waters.

Vertical centres of buoyancy above base. This curve also approximates to a straight line and gives the height of the centre of buoyancy above the keel for a given draught. It is measured horizontally from the vertical axis to the scale stated against the curve.

Transverse and longitudinal metacentres above base. The heights of the transverse and longitudinal metacentres above the keel for any particular draught are given by these two curves. The heights are measured horizontally from the vertical axis to the scale shown against each curve.

Moment to change trim one inch. This gives the moment in tons feet which is required to change the trim of the ship by one inch at any particular draught. It is measured horizontally from the vertical axis to the scale shown against the curve.

Tons-per-inch-immersion. This gives the weight required to be added or removed in order to change the mean draught of the ship by one inch at any particular draught. It is measured horizontally from the vertical axis to the scale shown against the curve.

Longitudinal centres of buoyancy. This curve gives the longitudinal distance of the centre of buoyancy at any particular draught from amidships. Amidships is indicated on the graph by the conventional mark comprising a circle, two semicircles and a vertical arrow. In this example the *LCB* lies before amidships, and the distance is measured horizontally from the line indicated to the scale shown against the curve.

Centre of flotation. This gives the longitudinal distance of the centre of the waterplane area at any particular draught from amidships. It is about a transverse axis through this point that the ship is assumed to trim, and its position is measured in a similar manner to that of the *LCB*. In this example it will be seen that the centre of flotation coincides with amidships when her draught is 26 ft.

Trim tables

The effects on the trim of the ship of loading or discharging cargo and filling and emptying the various tanks can be estimated from these tables. They also provide a means of estimating the position of the ship's centre of gravity at any condition of loading. Two separate tables are usually provided, one for the cargo

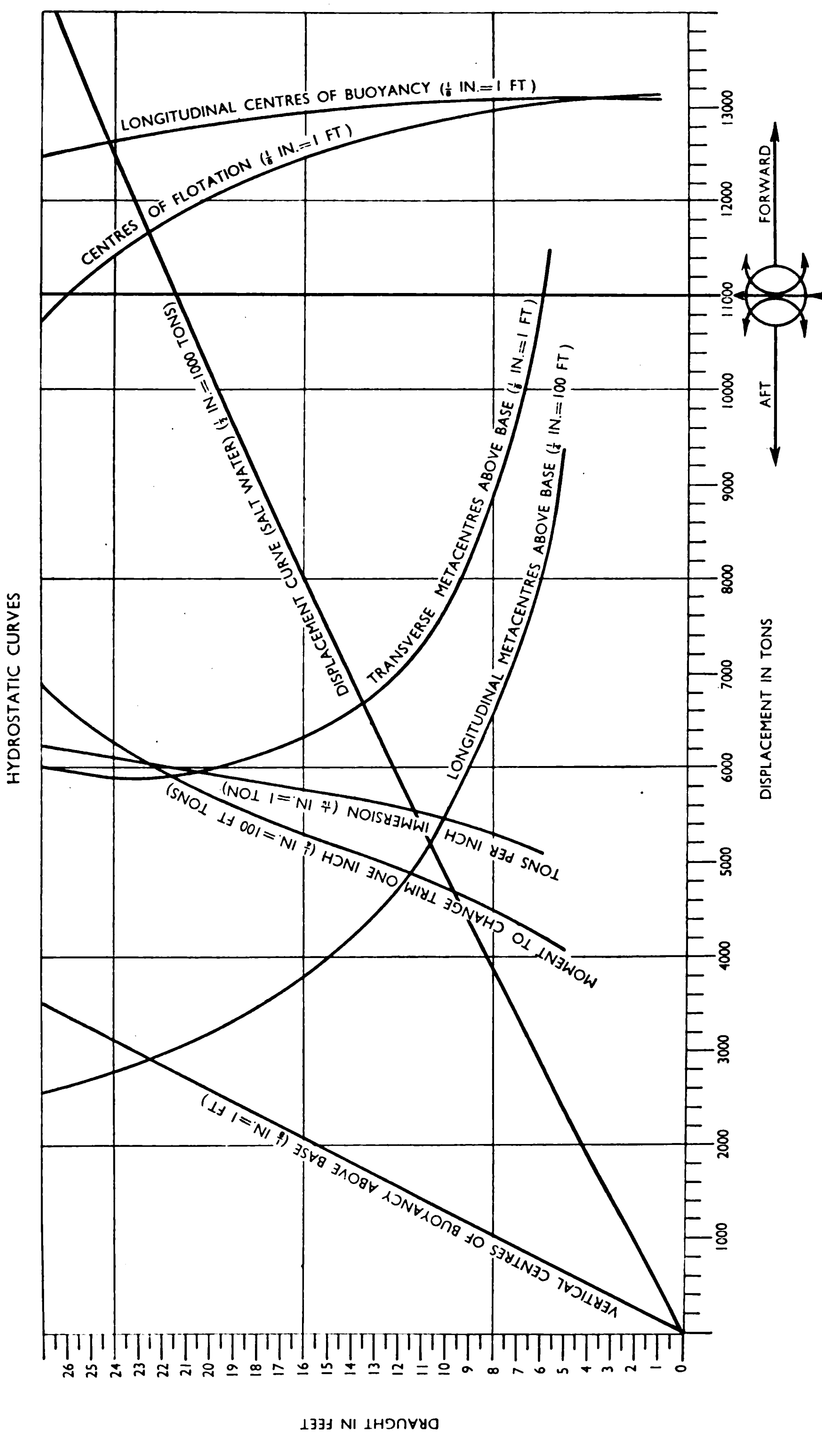


FIG. 1-9. An example of a collection of hydrostatic curves as supplied to a cargo ship

TANK CAPACITIES, TRIMMING SCALES & FREE SURFACE

COMPARTMENT	FRAMES	CAPACITY CU FT	TONS OIL FUEL AT 39cf/T	TONS WATER BALLAST AT 35cf/T	TONS FRESH WATER AT 36cf/T	EFFECTS ON DRAUGHTS BY FILLING TANK: TONS ADDED	23′ 0″ W.L. FOR'D	23′ 0″ W.L. AFT	17′ 0″ W.L. FOR D	17′ 0″ W.L. AFT	L.C.G. ABOUT MIDSHIPS	V.C.G. ABOVE BASE	FREE SURFACE MOMENTS: TONS OIL AT 39cf/T	TONS W.B. AT 35cf/T	TONS F.W. AT 36cf/T
NO. 1 C.D.B. TANK	139—164	2,634	67·5	75		80	$+6\frac{7}{8}$	$-3\frac{3}{4}$	$+7\frac{1}{2}$	$-4\frac{1}{4}$	160·7F	2·47	378	419	
NO. 2 ,, ,, P	110—139	4,684	120	134		275	$+16\frac{3}{4}$	$-5\frac{7}{8}$	$+17\frac{7}{8}$	$-6\frac{3}{4}$	101·88F	2·11	3,299	3,701	*
NO. 2 ,, ,, S	,,	4,684	120	134							101·88F	2·11			
NO. 3 ,, ,, P	81—110	6,693	171·5	191		390	$+13\frac{1}{2}$	$+2\frac{1}{4}$	$+13\frac{7}{8}$	$-2\frac{3}{8}$	36·54F	2·29	7,004	7,818	*
NO. 3 ,, ,, S	,,	6,693	171·5	191							36·54F	2·29			
F.W. TANK AFT	STERN-B.	517			14·2	14·2	—1	$+1\frac{5}{8}$	$-1\frac{1}{2}$	$+1\frac{7}{8}$	226·21A	31·01			
TOTAL DEEP TANKS, PEAKS, ETC.		66,142	64	1,704	96·0										
GRAND TOTAL		114,293	1192·0	2,961	211·0										

TO OBTAIN THE REDUCTION IN METACENTRIC HEIGHT DUE TO FREE SURFACE IN THE TANKS, DIVIDE THE MOMENT GIVEN ABOVE BY THE DISPLACEMENT (TONS) OF THE SHIP IN THE CONDITION UNDER CONSIDERATION. THE MOMENTS MARKED THUS * INCLUDE BOTH PORT & STARBOARD TANKS THE PORT OR STARBOARD FIGURES SEPARATELY BEING HALF THOSE STATED.

N.B.—THESE COLUMNS ARE INCLUDED FOR USE IN ASSESSING CHANGES OF TRIM BY LOADING

CARGO SPACE CAPACITIES

COMPARTMENT	FRAMES	GRAIN (CUBIC FEET)	BALE (CUBIC FEET)	EFFECT OF PLACING 100 TONS AT HATCH CENTRE IN HOLDS & TWEEN DKS. CENTRE OF COMPARTMENT ELSEWHERE: 23′ 0″ W.L. FOR'D	23′ 0″ W.L. AFT	17′ 0″ W.L. FOR'D	17′ 0″ W.L. AFT	L.C.G. ABOUT MIDSHIPS	V.C.G. ABOVE BASE
NO. 1 HOLD	139—164	38,748	34,130	$+8\frac{3}{4}$	$-4\frac{3}{4}$	$+9\frac{3}{8}$	$-5\frac{3}{8}$	158·45F	16·42
NO. 2 ,,	110—139	68,331	62,357	$+6\frac{1}{4}$	$-2\frac{1}{4}$	$+6\frac{3}{8}$	$-2\frac{3}{8}$	111·89F	13·72
NO. 3 ,,	81—110	60,246	52,961	+4	—	$+4\frac{1}{4}$	—	35·61F	22·63
TONNAGE WELL		1,634	1,548	$-5\frac{7}{8}$	$+9\frac{7}{8}$	—7	$+11\frac{1}{4}$	190·21A	35·91
TOTAL DEEP TANKS, SPECIAL CARGO, ETC.		91,225	83,521						
GRAND TOTAL		637,658	566,242						

NOTE:—TRIM FIGURES ARE CALCULATED ON MEAN DRAUGHTS OF 23′ 0″ AND 17′ 0″ AND ARE CORRECT FOR THOSE DRAUGHTS, BUT ONLY APPROXIMATE FOR ANY OTHER.

N.B.—THESE COLUMNS ARE INCLUDED FOR USE IN ASSESSING CHANGES OF TRIM BY LOADING.

FIG. 1–10. Typical example of trim tables as used by a cargo ship

spaces and the other for the tanks. A typical example of them is shown in fig. 1–10.

The trim table for the cargo spaces usually gives the grain and bale capacity of each space, the effect on the draughts forward and aft of placing 100 tons centrally on the deck of each space when the ship is floating at two or more selected mean draughts, the height of the centre of gravity of each space (i.e. the centre of its volume) above the keel, and the distance of the centre of gravity of each space before or abaft either the centre of flotation or the transverse centre-line.

The trim table for the tanks gives the capacity of each tank in cubic feet, the quantity (in tons) of fuel, salt water or fresh water which each will hold, the effect on the draughts of filling any particular tank, and the positions of the vertical and longitudinal centres of gravity of each tank. It also gives the free-surface moment of each tank when in the slack condition, which enables the reduction of the metacentric height due to free-surface effects to be calculated quickly by dividing the given moment by the displacement of the ship.

STABILITY DATA FOR A WARSHIP

Apart from the possible results of action damage, the variations in the loading of a warship are very small in comparison with those of a cargo vessel, and the stability data supplied to a warship therefore differ in form from those provided for a cargo vessel and are not nearly so detailed.

In wartime a warship must always be maintained in the highest possible condition of stability to ensure that she has the best chance of surviving even when seriously damaged below water. To fulfil this requirement it is usually necessary in cruisers and smaller vessels, where the weight of oil fuel and ammunition forms a greater proportion of the ship's displacement than in larger vessels, to arrange for the consumption of the oil fuel in a particular manner and also to flood certain tanks. These instructions are included in the stability data.

It may occasionally be necessary in special circumstances to use a warship for carrying cargo, but this should be done with discretion and only after a careful review of all the circumstances, because, apart from considerations of space, carrying cargo will probably reduce her stability to an extent which will leave an insufficient margin to enable the ship to withstand damage.

All stability data provided for a warship will be found in her *Ship's Book*, and additional copies are provided for use in the ship's ABCD headquarters.

Stability statement

The Director of Naval Construction provides every ship with a *Stability Statement*; this includes a certificate signed by him or his deputy to the effect that the stability of the ship is satisfactory. It is always made out for three particular conditions of loading, known as the *average action* or *half oil*, the *deep* and the *light* conditions (see fig. 1–11).

For each of these conditions the mean draught, the metacentric height, the angle of maximum righting lever, and the range of stability are given.

H.M.S. DRYAD

STATEMENT of METACENTRIC HEIGHTS and STABILITY Based on an Inclining Experiment made on H.M.S. Dryad on 5 March 1963

Conditions	Feet	Remarks
A. Average Action Condition The Ship when floating at a mean draught of 19 feet 6 1/4 inches, fully equipped, 1. (Cruisers and below), with all oil fuel tanks half full (*i.e.*, with 920 tons of oil), ~~2. (Capital ships, aircraft carriers, depot ships and monitors) with all double bottom and cross oil fuel tanks half full, all wing oil fuel tanks full (*i.e.*, with .... tons of oil), water protection compartments in use (*i.e.*, with .... tons water protection), and with reserve feed tanks full~~, has a metacentric height of	3·2	
B. Extreme Deep Condition The Ship when floating at a mean draught of 21 feet 1 inches, fully equipped, with all oil fuel tanks full (*i.e.*, with 1840 tons of oil), ~~water protection compartments in use (*i.e.*, with .... tons of water protection~~), and with reserve feed tanks full, has a metacentric height of	3·7	
C. Light Condition The Ship when lightened to a mean draught of 17 feet 0 3/4 inches, *i.e.*, when boilers and feed tanks are at working height, engine condensers full, one half the Central stores consumed, no fuel, water (including reserve feed), provisions, Canteen or Officers' stores on board, has a metacentric height of	2·0	

	Degrees			
	A	B	C	
The angles at which the Ship reaches her maximum righting moment in the above conditions, and beyond which the righting moment diminishes, are about	44	45	39	In arriving at these results, the ship is assumed to be intact with all external openings closed.
The angles at which her stability entirely vanishes in these conditions are about	89	OVER 90	71	

Notes:—(1) So far as stability is concerned the fuel and water may be worked in any manner desired by the Commanding Officer, but it is desirable to avoid having more tanks slack than is necessary.
(2) In ships provided with Flooding Boards, attention is directed to the information thereon concerning the procedure for correcting heel and trim in the event of damage to the ship.
(3) The "mean draught" is that obtained from the draught marks.
(4) In the above, the fuel tanks are termed "half full" or "full" when they are filled to $47\frac{1}{2}\%$ or 95% respectively of their total capacity.
(5) The "Average Action Condition," as defined above, is also used for the Flooding Board and Damage Control calculations.

Admiralty, 10 April , 1963

Director of Naval Construction.

FIG. 1–11. Example of H.M. ship's stability statement

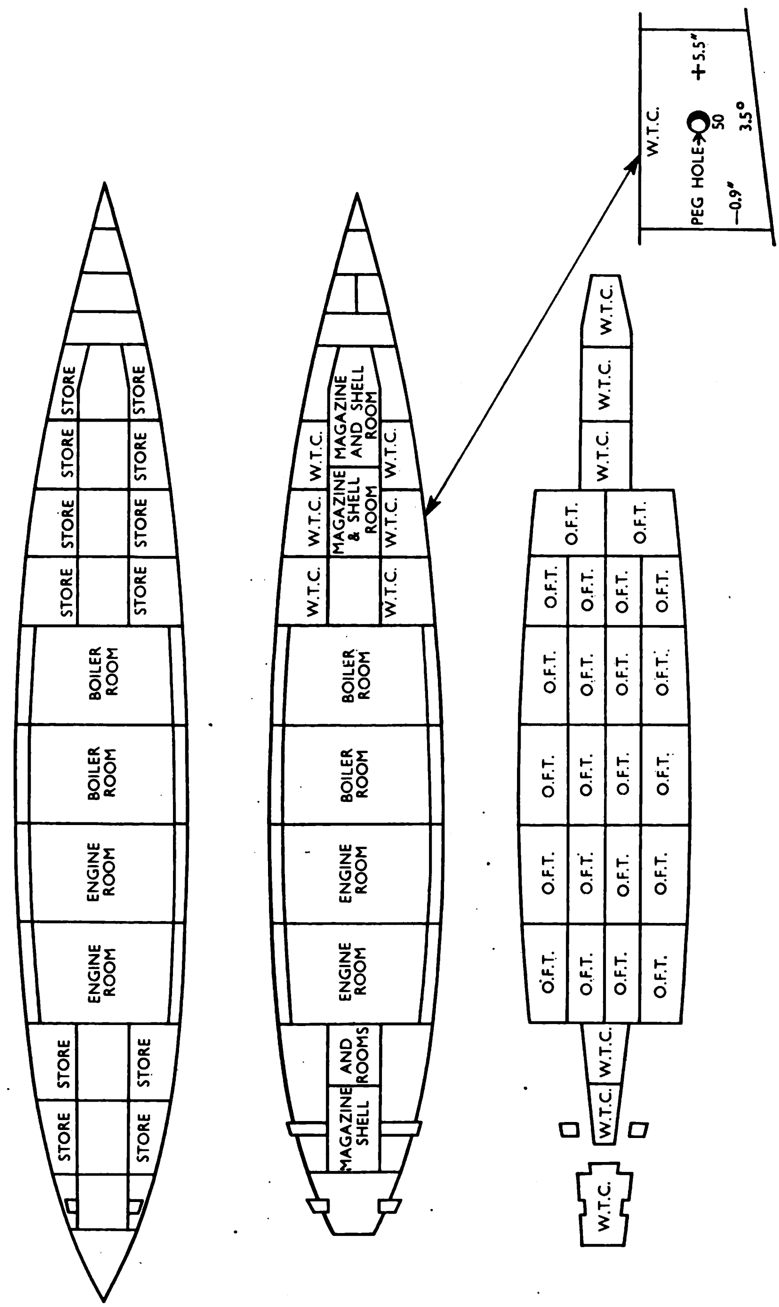


FIG. 1-12. A typical flooding board for a large ship

GZ curves

For each of the three conditions referred to on the Stability Statement, *GZ* or righting-lever curves are also supplied.

Hydrostatic curves

If curves are supplied they are generally similar to those for cargo ships as described above. There are differences in presentation, and one curve is added (*Change of displacement for one foot change of trim*) for use when severe damage at one end changes the trim by a large amount. A set of typical warship curves is shown and explained in B.R. 2171, *Ship A.B.C.D. Manual*, Vol. 2. Nowadays most ships are supplied with tables of hydrostatic particulars instead of curves, but the information is basically the same.

Pumping and flooding board

Cruisers and larger ships are supplied with a *pumping and flooding board*, which consists of a series of deck plans up to the level of the deep waterline. On it are shown the watertight subdivision of the ship, the capacity of each compartment in tons of salt water and its effect, when flooded, on the ship's heel and trim in the average action condition. Symbols indicate the method of pumping out each compartment. Colour washes are used to indicate the normal contents of a compartment (e.g. stores, water, oil, etc.) and the methods by which compartments can be flooded. Coloured pegs are used to indicate controlled or uncontrolled flooding, water or oil present before damage, and counterflooding.

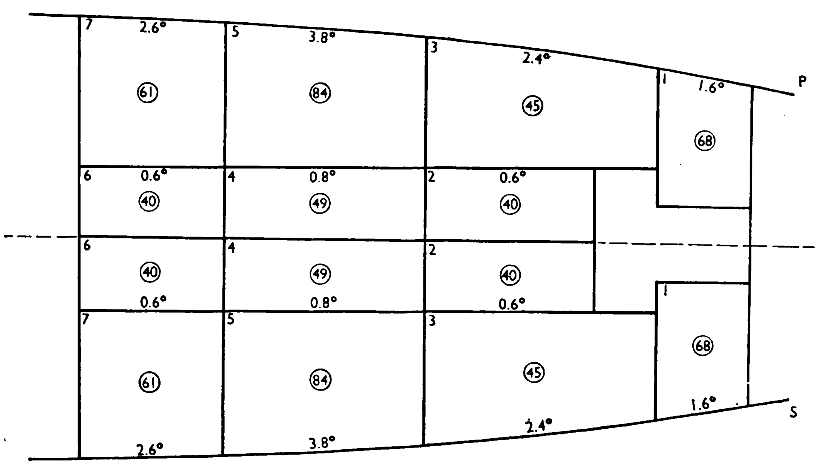


FIG. 1–13. Example of the use of a flooding board

Once it is known which compartments are flooded, the figures for each compartment can be added up, to give the total *flooding-board heel and trim.* If the ship is stable, she can be restored approximately to the upright by transferring liquids within her, by counterflooding, or by both. Some ships are fitted with rapid-flooding compartments with direct access to the sea for deliberately flooding compartments on the high side. This decreases reserve of buoyancy

and increases draught, but is relatively quick. Transfer of liquids from the low to the high side is slow, but has double the effect of counterflooding and does not reduce reserve buoyancy.

The two methods *could* be used as follows (see fig. 1–13):

Suppose that P3 and P5 tank are flooded. The flooding-board heel will be 2·4°+3·8°, a total of 6·2°. The ship can be restored to the upright by transferring liquid from P1 and P7 (total capacity 129 tons) to the empty tanks S2, S4 and S6 (total capacity 129 tons), thereby providing heel to starboard of 1·6°, 2·6°, 0·6°, 0·8° and 0·6°, a total flooding-board heel of 6·2°; or counterflooding by filling empty tanks S3 and S5, providing starboard heel of 3·8° and 2·4°, a total of 6·2°.

In fact, counterflooding would not be used against a heel of only 6·2°. Also, when restoring heel it is possible to recover some trim by using tanks diagonally opposed to the flooding.

FLOODING AND COUNTERMEASURES

When practicable the list of a damaged ship should be corrected by transferring liquid from one compartment to another, because this does not entail any loss of the ship's reserve of buoyancy. It is, however, a rather slow method, involving additional free-surface effects during the transfer; and in warships, where a quick return to the upright may be essential, counterflooding may be preferable.

Counterflooding is a fast method of curing a list, and in large cruisers and all larger warships suitable wing compartments are fitted with flooding valves so that they can be filled direct from the sea. If a ship is badly damaged and listing 10° or more, counterflooding should be carried out immediately.

But it should be realised that counterflooding has its disadvantages. It reduces the reserve of buoyancy and sinks the ship lower in the water, and so decreases her speed and manœuvrability. It should only be used as necessary to get the ship back to a manageable state as quickly as possible, which generally means reducing the list to about 6°, at which angle the ship can be manœuvred and fought. Thereafter such measures as transferring liquids, repairing damage and pumping out compartments will further reduce the list and may even allow some reserve of buoyancy to be regained by pumping out compartments which have been counterflooded.

In destroyers and smaller ships, where there is little longitudinal subdivision, damage incurred below the waterline may result in the ship taking large quantities of flood water into one or more of her main compartments, her engine and boiler rooms, for example. The free-surface effect of the large area of this water may reduce the metacentric height to such an extent that the ship will have a negative metacentric height and float unstably, lolling from side to side under the influence of the waves or wind. In such a case it would be dangerous to attempt to correct any heel by transferring liquids or by counterflooding; the only countermeasures which should then be attempted, until a degree of positive metacentric height has been regained, are:

1. isolating, subdividing and pumping out any compartments containing free-surface liquids:

2. filling to the crown tanks low down in the ship, including those which already contain liquids;
3. jettisoning movable topweight symmetrically from about the longitudinal centre-line.

To summarise, transference of liquids should be regarded generally as being the best method of correcting a list. When it is essential that the damaged ship should be returned to the upright as quickly as possible, counterflooding is preferable, but it should be done as soon as possible after the ship has listed, its use should be restricted to the minimum necessary to bring the ship to a safe or manageable state, and later, when other measures are in hand, it should be reduced as much as possible. In small ships it is imperative to distinguish between the conditions of *list* and *loll*, because the remedies for each are so different; if the ship is in a state of loll it must be corrected before any measures are taken to counter list. The two conditions are described in detail in Volume II.

STABILITY AND TRIM OF SUBMARINES

This section is not intended as a treatise on the stability and trim of submarines, but merely to indicate the great differences between the problems of stability of these vessels and those of surface ships.

Transverse stability

The transverse stability of a submarine floating on the surface can be estimated in a similar manner to that of a surface ship. From fig. 1–14 it can be seen that

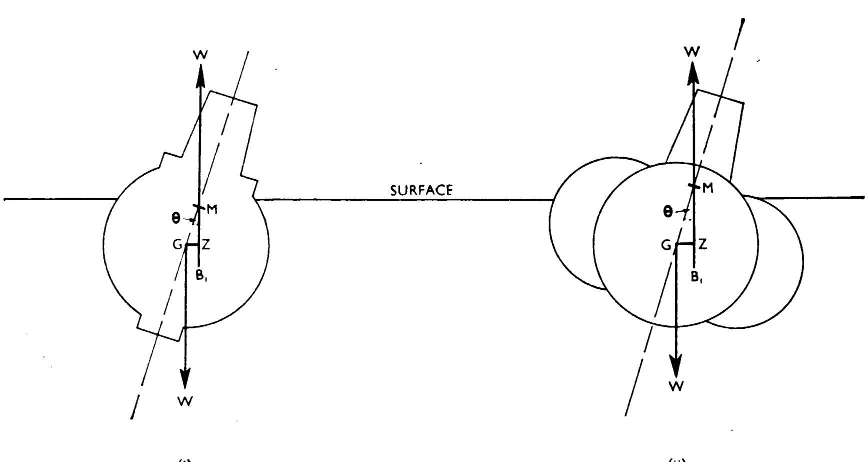


FIG. 1–14. Transverse stability of surfaced submarine

as the vessel heels her centre of buoyancy B moves to B_1 on the low side, producing a righting couple, $W \times GZ$, where $GZ = GM \sin \theta$ for small angles of heel. At larger angles of heel the saddle-tank type of submarine (fig. 1–14(ii)) is

likely to have better stability than the single-hull type (fig. 1–14(i)) because of the broader waterplane area of the former.

When a submarine is completely submerged, however, she has no waterplane and therefore no waterplane inertia, and her metacentre M will then coincide with her centre of buoyancy B. Moreover, B will become a fixed point irrespective of any angle of inclination, because the underwater form of the vessel will not change as she heels. In order, therefore, to provide the necessary righting moment when the submarine is heeled, her centre of gravity G must be below her centre of buoyancy B, as shown in fig. 1–15(i) and (ii), thus providing the

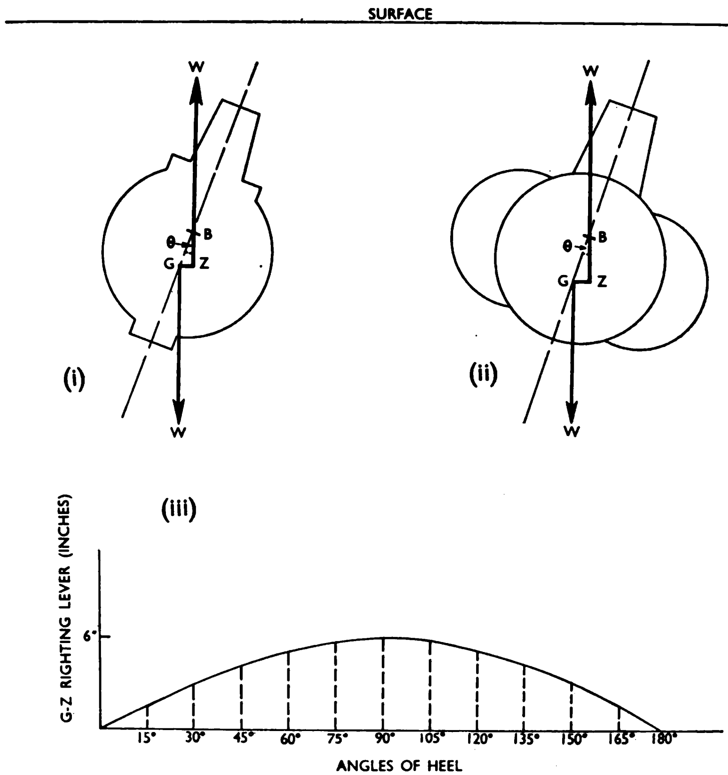


FIG. 1–15. Transverse stability of submerged submarine

righting lever GZ, which will be equal to $BG \sin \theta$. The distance BG can be taken as constant, if any small movement of G due to free-surface liquids is disregarded, and the GZ curve will therefore become a curve of sines as shown in fig. 1–15(iii). From this curve it will be seen that the angle of maximum GZ is 90°, that at this angle $GZ = BG$ and that the range of stability is 180°.

The length of BG gives a measure of the stability of a submerged submarine, and corresponds to the GM of a surface ship. The BG of a submerged submarine is usually less than her GM when on the surface, except in single-hulled vessels, where the reverse is usually the case.

Longitudinal stability and trim

The longitudinal stability of a submarine when on the surface can be estimated in the same way as that of a surface vessel from the formula:

$$M.C.T.1'' = \frac{W \times GM_L}{12L} \text{ as described on page 18.}$$

When the submarine is submerged, however, her longitudinal metacentre M_L will, like her transverse metacentre, coincide with her centre of buoyancy, and her GM_L will then be equal to BG (see fig. 1–16). Since the length of BG is usually only about 6 inches it will be seen that her longitudinal righting moment is very small indeed, and that consequently she will be very tender longitudinally when submerged. This tenderness makes it necessary to limit

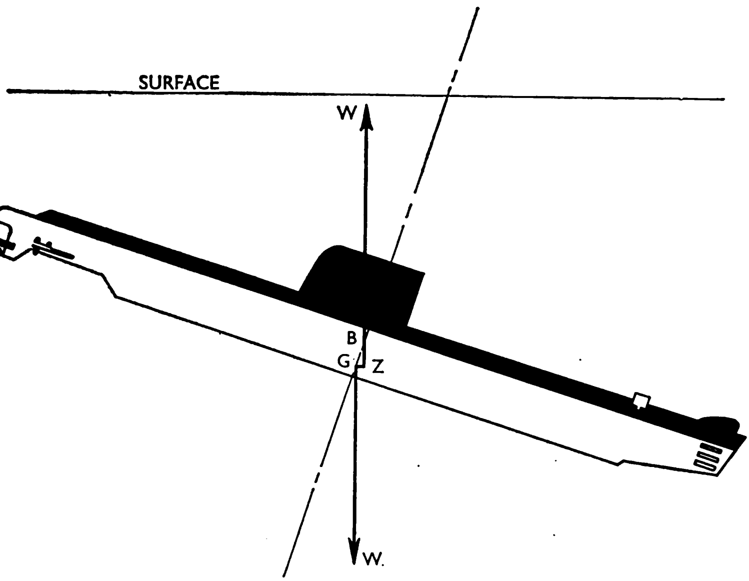


FIG. 1–16. Longitudinal stability of submerged submarine

and to control accurately the movement of any weights along the vessel; it is, however, an advantage because it enables her trim to be controlled by reasonably small hydroplanes, and ensures that she can change depth rapidly, which would not be practicable if she had the longitudinal stiffness of a surface ship.

GROUNDING

A ship may ground accidentally. On the other hand, she may be beached deliberately, possibly to prevent total loss (see page 129). The problems of salvaging stranded ships are dealt with in Chapter 7. The remarks that follow concern the stability of a grounded ship, and indicate the dangers involved in dealing with this aspect, and some possible precautions.

A grounded ship is in a very similar condition to a ship being docked. She is no longer a floating body; the upward pressure of the ground on the ship's

bottom has exactly the same effect as if an equal weight were removed at that level, i.e. the centre of gravity rises and *GM* is less. The greater the pressure on the bottom, the greater the rise of *G*. The greater the fall of tide, the greater the pressure; and it reaches a maximum just before the ship grounds along her length.

In dry docking, a stage is always reached when this virtual rise of *G* is equal to *GM*—when metacentric height becomes nil. Before this stage is reached the ship is prevented from heeling by either shores or side-docking keels. Whether a grounded ship becomes unstable or not depends on her stability at the time of grounding and on how far the water falls after grounding. If a ship grounds near low water, stability is not likely to be endangered by grounding alone. Even if grounding is near high water, if the ground is fairly even and soft most ships will settle into a bed of their own making and not fall over. The danger comes when a ship grounds on a hard and uneven bottom and the tide has some distance to fall. The ship may then become unstable as the tide falls and lie over on her side, with resultant damage and further flooding as the tide rises, causing complete loss of the ship.

The principal maxim to remember is this: The normal seamanlike precaution of filling bottom compartments to weigh down the ship and minimise working and pounding on the bottom is equally effective in giving a greater measure of stability as the tide falls. This, together with the emptying of high tanks and the removal of any other weight above the centre of gravity, should materially help to prevent a stranding from becoming a much more costly salvage job or perhaps a total loss.

CHAPTER 2

Pumping and Ventilating Systems in a Warship

The maintenance of the pumping and ventilating systems and the water services of a warship is normally the responsibility of the technical branches, but the seaman should have a good knowledge of how they work and how they can best be used for the various purposes for which they are designed. In Volume I, Chapter 3, there is a brief outline of the functions of these systems and in the present chapter the more important details are described. In particular, the seaman should be familiar with his ship's pumping and flooding systems, as a necessary adjunct to his understanding of stability, which is described in the previous chapter and also in Vol. II. The use of pumps and water services such as the ship's *firemain* for firefighting is described in the chapters on this subject in Vols. I and II.

PUMPING ARRANGEMENTS

Pumping out compartments

To avoid penetrating the main transverse bulkheads below the water-line, most warships are so designed that there are independent pumping arrangements in each main transverse watertight subdivision. In certain older ships, however, *a main suction line* is fitted, extending nearly throughout the length of the ship, sometimes in the form of a ring main and usually low down in the ship. Compartments can be pumped out by permanent suction leads or portable hoses connected to the suction main.

Salt-water services

The salt-water services in a ship are supplied from a main service pipe which is generally called the firemain (see Vol. I, Chapter 5). In small ships this is a single-line pipe system running the length of the ship, but in larger ships it takes the form of a ring main, within the protected part of the ship, with suitable cross-connections and single-line extensions to the ends of the ship. The firemain is supplied through risers from the fixed pumps described later in this chapter. Numerous branches are taken from the firemain, each having an isolating valve close to the main, for supplying domestic services, wash-deck arrangements, pre-wetting, magazine spraying and other services.

Under action conditions the system can be isolated into sections by suitably placed valves, each section being supplied by its own pump. This will limit flooding or loss of pressure from a damaged section of the main and enable hoses to be rigged from branch connections off the rising mains to connections on the undamaged part of the firemain.

When the pumps are working on the firemain in normal conditions, water is continually being drawn off for sanitary and other services. In action, however,

when the firemain is isolated into sections, there may be no draw-off and this may cause the pumps to overheat. To obviate this, arrangements to enable each pump to discharge overboard are fitted.

The working pressure of the firemain varies from 75 to 100 lb per sq. in., and in aircraft carriers a separate flight-deck firemain is fitted and works at 100 lb per sq. in. Such pressures are too high for some subsidiary services such as sanitary systems, so reducing valves are fitted at the branch connections to the firemain.

Function of pumps

The principal functions of the pumps and eductors in the pumping, flooding and draining systems are:

1. To supply water for domestic services such as sanitary arrangements, bathrooms and washing decks.
2. To supply water for cooling of gunnery, electrical and air-conditioning equipment, etc.
3. Routine pumping out of compartments in which water collects during normal service, such as machinery spaces, bilges, gland spaces and sonar compartments.
4. Routine transfer of water for de-ballasting, etc.
5. To supply, under pressure, water for firefighting and spraying of hangars and magazines.
6. The pre-wetting of weatherdeck structure to reduce residual contamination from radioactive fall-out.
7. To pump out flooded compartments after action or other damage (i.e. for *salvage duties*).
8. To flood certain compartments to correct heel and trim.

In modern ships built-in pumping systems are provided for all these functions except salvage duties. Experience has shown that built-in salvage systems are not only vulnerable, but unreliable when a ship has been damaged, and for salvage a modern ship is provided with electrically-driven portable pumps. In large ships there is normally one supplied for each main watertight subdivision, and in frigates and smaller ships there is usually one at each end of the ship.

In a large warship the total pumping capacity may be of the order of 40,000 tons per hour. But a 1 ft-square hole in the ship's side 25 ft below the waterline will admit water at the rate of about 3,500 tons per hour, so it will be obvious that even if all the ship's pumps could draw in one place they could not cope with the influx from heavy underwater damage. To save a damaged ship reliance is placed on watertight subdivision rather than on pumping power.

TYPES OF PUMP

The principal types of pump used in H.M. ships are as follows:

Main circulating pumps. These are in the engine rooms of steam-driven ships and are intended for circulating sea water through the condensers, but they can also be used in emergency for pumping large quantities of water out of the ship.

Submersible salvage pumps. Salvage duties are carried out in modern ships by portable electric pumps, but in some older ships fixed submersible pumps are fitted for this purpose. They can deal with large quantities of water, and are connected to permanent suction pipes led to compartments such as magazines, shell rooms, the spirit room and auxiliary machinery compartments. They are electrically driven. Because of the low head of water at which the pumps work they are not connected to the firemain.

Emergency bilge pumps. These are fitted in large ships in the boiler rooms, gearing rooms and, in some cases, engine rooms. Each pump is situated on the inner-bottom plating, takes its suction from a *strum* (a valve box in the outer bottom space with a perforated cover) and discharges overboard. Its motor and controls are on the deck above, driving it by a flexible shaft. Capacity is of the order of 1,000 tons per hour. The pumps are either electrically or turbo-driven.

Fire pumps. These are single-duty non-submersible pumps designed to supply solely the main service system that includes the firemain. They are sited below the waterline, both inside and outside the main machinery spaces.

Fire and bilge pumps. In older ships having a main suction line these fixed pumps are sited in the machinery spaces. They can be used to pump out the bilges or certain adjacent compartments, or to pump water from one tank or compartment to another, or to provide water for the firemain. They are of the self-priming centrifugal type and are either electrically or turbo-driven.

Hull and fire pumps. Also found in older ships with a main suction line, these pumps are fitted *outside* the machinery spaces, and can be connected either to the firemain or the bilges. They are electrically-driven, self-priming pumps.

Portable pumps. For salvage duties in pumping out damaged compartments various types of portable diesel and electric pumps are provided.

Air-driven submersible pumps. These are small portable pumps of about 38 tons-per-hour capacity and 60 lb weight. They are provided in aircraft carriers and other ships where danger would exist in compartments containing highly inflammable liquids or vapours if pumping was done by electric or turbine power.

Eductors. These are ejectors, which are operated by high-pressure water from the firemain. They have a variety of uses, from the cleaning of bilges at 15 to 40 tons per hour to de-ballasting at 150 tons per hour. They are simpler to operate than pumps and have no moving parts to maintain.

SPRAYING, FLOODING AND DRAINING ARRANGEMENTS

Spraying

All magazines, spirit rooms and inflammable stores have spraying arrangements. Systems for spraying the hangars of aircraft carriers and petrol control compartments are also provided.

Magazines. The spraying system in a magazine is independent of the flooding system (see below) and consists of a grid of pipes fitted with a number of sprinklers so as to cover the whole of the ammunition stowage. The grid is supplied from the firemain through valves that can be controlled either from inside or outside the magazine.

Petrol control compartments. These are sprayed from branches led off the firemain, the control valves being worked from inside the compartment and from adjacent lobbies.

Hangars. The spraying system is fed by electrically-driven pumps, each having a capacity of about 150 tons per hour and taking its suction from an independent seacock. A ring main serves a grid of pipes fitted with sprinklers in each hangar section. Cross-connections are fitted to enable the hangar spray supply to be supplemented by the firemain. The pumps that work the sprays can be started by switches in the hangar access lobbies and in the hangar control positions.

Flooding

Most magazines and shell-rooms and some inflammable store rooms can be flooded, usually direct from the sea, seacocks being provided for the purpose. The flooding arrangements of each magazine should be capable of completely flooding it within 15 minutes when it is fully stowed.

In large ships flooding arrangements are also fitted to certain compartments for the purpose of counteracting heel or trim. Air escapes are fitted to all compartments for which there are flooding arrangements. Where a compartment is flooded from the firemain, special care must be taken to ensure that the compartment is not subjected to too much pressure.

Flooding bonnets are provided for the sea inlets of compartments such as magazines so that they can be flooded when the ship is in dry dock. The gratings of the sea inlets are removed and the bonnets secured over the inlets directly the ship is dry-docked. Hoses are then rigged between the bonnets and the shore hydrants.

Control of spraying and flooding arrangements

Seacocks and flood valves are operable from a flooding cabinet, also from a position immediately outside the compartment, and sometimes from a third or emergency position, depending on the protection afforded to the two former positions.

Spray valves are operable from three positions, one outside the magazine, one at the flooding cabinet and a third or emergency position (unless the size of ship renders the third position impracticable, e.g. there are only two positions in frigates and ships of similar size).

Flooding cabinets are sited in positions selected to give ease of access combined with as much protection as possible.

Draining

Scuppers are fitted at intervals at the outboard edges of the weather decks, and sometimes at the sides of spaces or compartments on other decks if they are well above the waterline. The scupper pipes are led within and close to the ship's side, and they emerge through it just above the waterline, where they discharge through storm valves of the positive-closing type.

In machinery spaces, sumps for collecting bilge water are fitted to the inner bottom. Certain compartments can be drained into adjoining ones which are

fitted with suction pipes and so can be pumped out, sluice-valves being fitted wherever a watertight bulkhead is penetrated.

Bathrooms and washplaces drain into sumps. When situated well above the waterline the sumps drain directly overboard, but when close to the waterline they are cleared by eductors.

FRESH WATER

Storage

Fresh-water storage tanks are usually compartments in the ship's structure, low down in the ship. They can be filled through the distiller main either from water-boat connections forward and aft on the weather decks or from the ship's distilling plant. Funnels are fitted in the filling lines just above the tanks to prevent a build-up of pressure in them. Transfer of water in the ship is by fresh-water pumps through the distiller main.

Distribution

The system most used nowadays is the continuous-running pump system in which the fresh-water pumps discharge continuously into the fresh-water distribution main, each pump being provided with a pressure-controlled leak-off back to the tank. Some ships are fitted with the pressure-tank system, in which the pumps are controlled by the air pressure above the water in each of two pressure tanks. Some older ships have a system in which pressure in the main is supplied by gravity tanks with electrically-operated float switches controlling the pumps. The main is usually in two or more sections, with valves for isolating them or connecting them together.

Hot water

One or more hot water systems are provided, according to the size of ship, each with its own circulating pump and steam, electric or oil-fired water heater. Water is circulated in a flow-and-return loop by convection, assisted where necessary by a booster pump. Where more than one system is fitted they can be cross-connected.

Drinking water

Cooled fresh water is supplied for drinking on messdecks and at other convenient points. Special emergency electrically-heated hot-water tanks are provided in such places as the Sick Bay and the Emergency Operating Station.

VENTILATING AND AIR-CONDITIONING SYSTEMS

The ventilating system of a warship must be able to function efficiently in all climates from arctic to tropical, and it must therefore be flexible in operation.

To be efficient, ventilation must not only provide enough pure air for breathing, but it must also maintain an atmosphere in which a man can work in reasonable comfort. This depends on the temperature and humidity of the air outside the ship, its movement and circulation in the compartment to which it is delivered, and the removal from the compartment of used and foul air.

Generally speaking, the drier the air—within limits—the better is the atmosphere. A man feels fitter and more comfortable, and so works better, in a dry atmosphere than in a humid one, and this is particularly so in extreme heat or cold. Air movement, such as a breeze or a draught, has a cooling effect which is an advantage in hot climates and a disadvantage in cold ones. Efficient ventilation is more easily attained in arctic than in tropical conditions. In tropical climates satisfactory living and working conditions in a ship cannot be achieved by ordinary fresh-air ventilation, and therefore air-conditioning is used as much as possible.

Ventilation in arctic conditions

Efficient ventilation in arctic weather is provided quite simply by incorporating heaters in the ventilation trunking and by supplying no more fresh air than is required to keep the atmosphere in a compartment breathable.

It is possible to heat all the air in the ship to about 65° F, but this may result in drying the air so much that it irritates the throat. Therefore it is usual to heat only the limited intake of fresh air and to use part of the fan capacity to recirculate air within the ship.

Ventilation in the tropics

Efficient ventilation in tropical climates is difficult because of the very high humidity of the atmosphere and the consequent need both to cool and to dry the air within the ship. High humidity prevents free evaporation of sweat from the skin, which is one of the body's heat regulators, and in consequence heat exhaustion is brought on more quickly.

Air-conditioning

The need to cool and dry the air is not confined to tropical climates, though it is there more pressing. Cooling is imperative in compartments that contain, for example, electronic equipment such as radar which releases an enormous quantity of heat that must be removed in order to prevent damage. For personnel a comfort zone between certain limits of temperature and humidity can be established, and the purpose of air-conditioning is to maintain the atmosphere in the compartments within these limits. The demand upon the equipment varies, of course, with the numbers of men in the compartments and the ambient temperature.

An air-conditioning plant is therefore basically a refrigerating machine through which the air is circulated by fans. In this process the air temperature is lowered to a point at which part of the contained moisture condenses on the cooling surfaces of the machine and drains away. The air, therefore, leaves the plant cooler and drier.

Air-conditioning systems usually take in a proportion of air from the atmosphere, recirculate the remainder and both cool and dry the entire flow.

In any compartment that is air-conditioned it is important that doors or other openings be opened no more than is essential, because every time one is opened there is an inevitable rise in temperature and humidity. Likewise, smoking should be restricted to prevent undue fouling of the air, only part of which is being replenished from atmosphere. A typical air-conditioning system for a compartment, embodying recirculation, is shown in fig. 2–1.

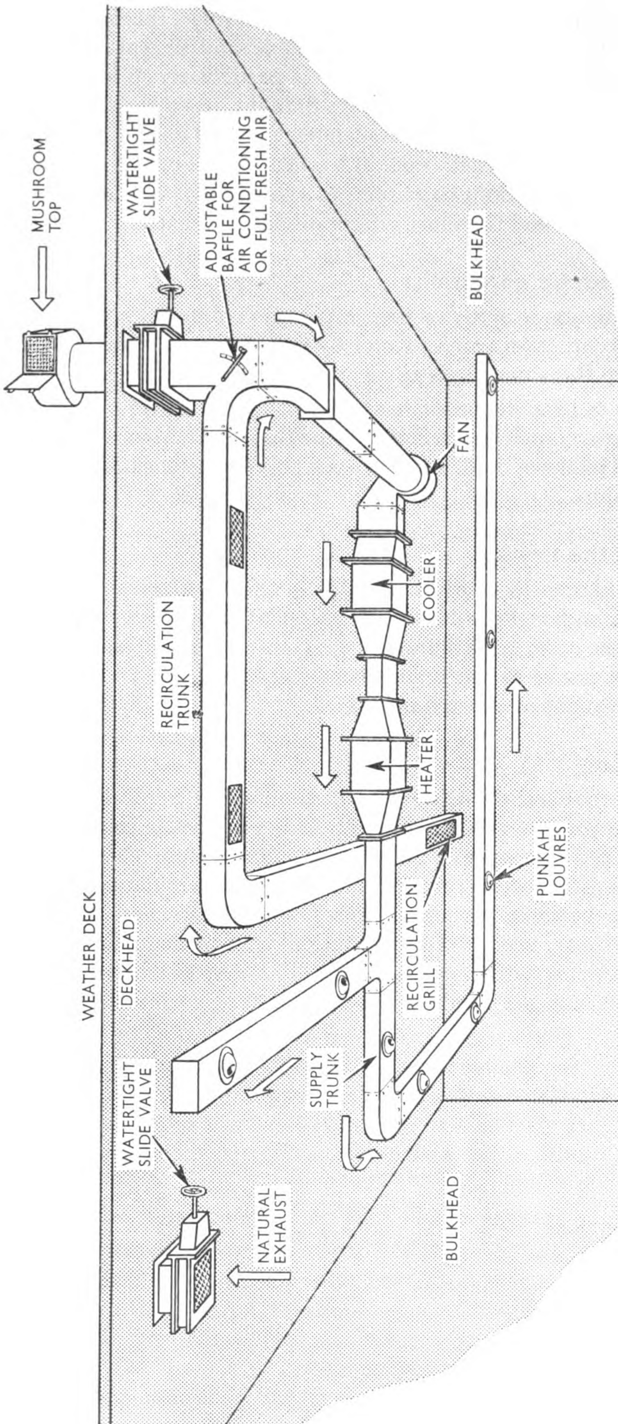


FIG. 2-1. Typical air-conditioning system for a compartment

Tropical conditions within the ship

It is impracticable to provide the entire ship with air-conditioning, and outside the air-conditioned spaces the policy is to supply large quantities of air at relatively high speeds in order to keep the atmosphere in continual circulation and movement, thus scavenging compartments of heat and foul air while at the same time providing a breeze.

An efficient exhaust system is most necessary to ensure that the air in a compartment is completely changed at frequent and regular intervals, and also to prevent any pressure being built up in the compartment which would reduce the efficiency of the fans. Under these conditions the fans must be maintained in a high state of efficiency, because they will be running continuously at full speed.

To determine ventilation requirements in the tropics a scale of temperature known as the *effective temperature* is used. This scale takes into account the dry-bulb temperature and the humidity and movement of air in a compartment in comparison with the atmospheric conditions in the open air. Health and efficiency deteriorate when the effective temperature exceeds 86° F.

Tropical air conditions over the open sea correspond on average to an effective temperature of 82° to 83° F at low air speed, but are usually higher near land. The mean temperature within the ship, however, is always greater because the ship herself generates heat from her machinery, boilers and galleys, and the men living and working in her give off heat. In the tropics there is, therefore, little margin between the effective temperature within the ship and the critical effective temperature of 86° F. The condition can be alleviated by passing large quantities of air through compartments at high speed, thus eliminating as far as possible any *wild* (i.e. unnecessary) heat and lowering the effective temperature.

The quantity of air required in a compartment depends upon the heat within it; for living spaces it is usually between 30 and 35 cubic feet per minute per man, and this must be provided at an air speed of between 100 and 300 feet per minute.

The amount of wild heat in a compartment can be reduced by:

1. lagging steam and hot-water pipes, deckheads in compartments directly below the weather decks, the ship's side in side-compartments above the waterline, and bulkheads adjacent to hot compartments;
2. removing hot air from particularly hot places, such as galley ovens and domestic water heaters, by special exhaust fans and trunking;
3. cooling the weather decks and the ship's sides by playing water from the firemain on them with wash-deck hoses;
4. switching off all unnecessary heat-producing equipment and electric lighting.

Methods of ventilation

From the foregoing it will be seen that ventilation requirements for tropical conditions govern the design of the ventilation system of a warship. In many older ships most of the compartments are ventilated in the way described below, but in modern construction operational and living spaces are air-conditioned

on the lines of the typical arrangement shown in fig. 2–1. Even in the older ships some measure of air-conditioning is used in various ways, including the use of self-contained air-conditioning units. Compartments that especially require air-conditioning are those in which the occupants must be mentally alert, e.g. rooms in the Action Information Organisation, the ABCD Headquarters and certain magazines.

Ventilation arrangements in non-air-conditioned compartments are generally as follows:

1. *Living and working compartments* in which no great heat, harmful gases, or smells are generated: examples are messdecks, workshops not fitted with furnaces, store rooms in regular use, and offices. Such compartments have a forced supply and a natural exhaust, the air being led to positions normally occupied so that the occupants receive air that is nearly as fresh and clean as the open air. If the compartment is more than one deck below the weather deck, or the exhaust trunking does not provide a free flow for the used air, a forced exhaust is fitted instead of a natural one.
2. *Compartments in which heat, smells or harmful gases are produced*, examples being occupied power rooms and radar rooms. Such compartments have a forced exhaust and a natural supply, and in addition a small forced supply is directed to positions where the occupants normally work. The exhaust and supply are regulated so that pressure in the compartment is slightly less than the pressure outside it, thus preventing the heat, smell or gases from penetrating into adjacent compartments.
3. *Compartments in which great heat is generated*, such as engine rooms and galleys. These compartments have a forced supply and a forced exhaust, so regulated that the rate of supply is slightly less than that of the exhaust to ensure that no hot air escapes into adjacent compartments. The supply is concentrated at positions where the occupants normally work, and to other positions which provide havens into which men can go to obtain relief from the hot air around them. The exhaust is concentrated at the places where most heat is generated, thus ensuring that the overheated air in the vicinity does not escape into other areas and so raise the temperature throughout the compartment.

   Boiler rooms can be included in this category, and in these compartments only forced ventilation is provided by powerful forced-draught fans. Some of the incoming air is diverted to the watchkeeping positions, but most is passed round the boilers, thus heating the air before it enters the furnaces and also helping to lag the boilers. The exhaust is by way of the funnels from the boilers and through exhaust outlets from the boiler room.
4. *Compartments which are infrequently used* and which do not require a constant supply of air, such as unoccupied store rooms. Such compartments are ventilated only when required, either by fixed fans or by portable air-hoses led from nearby connections specially provided in the permanent ventilation system. Certain store rooms that are seldom entered require ventilating at regular intervals, and to ensure this a routine should be laid down.

Air supply terminals

These consist of punkah-louvres, distributors, bellmouths and slots.

The *punkah-louvre* directs a stream of air from the supply trunk in any direction within a cone the angle of whose apex is about 85°, and it has an effective range at normal working pressures of some 6 to 12 ft, depending on its size. This air stream is of great advantage in hot climates. In cooler weather the air velocity can be reduced by running the fans at a lower speed, and the punkah-louvres can be adjusted to direct the air flow away from the occupants of the compartment. The modern louvre is so made that if the ball is reversed the jet will be changed to a diffused air supply, which is more pleasant in cold weather.

Distributors are usually employed in air-conditioned compartments to ensure that cold air entering is mixed with the air in the compartment.

Bellmouths, for delivering large volumes of air, are used only in hot compartments such as engine rooms.

Slots are specially useful where curtains of air are required for shielding personnel from radiated heat, as in galleys. The air curtain can be delivered from any suitable direction.

Ceiling and table fans

These fans are fitted to increase air movement and assist in circulating the fresh or conditioned air being discharged by punkak-louvres, distributors, etc. They do not remove heat or moisture and are not essential in properly air-conditioned spaces, although they are sometimes fitted to avoid dead spots in the air distribution.

Arrangements for preserving watertight integrity

Main transverse and longitudinal watertight bulkheads are not penetrated below the highest 'all-red' deck by ventilation trunking. Watertight trunking in modern ships is provided wherever the trunks are a potential source of further flooding, and they are fitted as necessary with watertight slide-valves. Suitable positions for operating the valves are chosen to facilitate the control of flooding or fire in the event of damage.

Supply inlets and exhaust outlets are fitted above the weather decks, in positions least likely to be affected by seas and spray. The exhaust outlets are usually higher than the supply inlets and they are kept as far from them as possible so that the foul air from the exhaust will not be drawn back into the ship and recirculated. Inlets and exhausts are usually fitted with water-excluding heads of the 'French' type, or with hinged watertight covers.

The need to preserve watertight integrity, and also to meet the threat of attack by atomic, biological or chemical warfare, has led to the development of the *section system* of ventilation. This consists essentially of two main axial-flow fans, one supply and one exhaust, together with ducting systems arranged to distribute air within, or exhaust air from, a section of the ship. In large ships the section would usually be bounded by two main transverse bulkheads, but in smaller ships, e.g. frigates, the section might extend through several such bulkheads. The closing down of the ship against gas and similar types of attack is greatly facilitated by having only a few openings. Recirculation of the air within the section is possible by means of recirculation flaps in the main fans.

Citadel

Citadel is the term applied to the main group, or to each group, of interconnecting compartments which can be conveniently grouped together within an unbroken gastight boundary. Each citadel should be provided with a means for recirculating air. An important feature of a citadel is that within it the air pressure can be raised slightly above the normal, so that if there is any small breach in the citadel, the pressure tends to blow away and outwards any harmful agents and to prevent their entry. The pressure is built up by sucking in air from outside the ship through *air filtration units*, so ensuring that the air within the citadel is filtered and pure.

Normally the citadel (or citadels) in a warship embraces the bridge superstructure below the compass platform and any other superstructure which can reasonably be included. In aircraft carriers the island up to the top deck is usually included in a citadel.

Organisation of ventilation

The control of ventilation in a ship, especially in the tropics, requires an efficient organisation to ensure on the one hand that there is adequate ventilation for the ship's company, and on the other that the watertight and gastight integrity of the ship is maintained. The ventilation and integrity patrols require an intimate knowledge of the section of the ship in which they work. Ventilation routines have to be prepared to meet the requirements of the different climates and the different tactical conditions in which the ship may be employed.

Immediately the ventilation inlets on the weather decks are shut down, heat and humidity within the ship increase appreciably, so it is important that the inlets should be left open for as long as possible before the higher states of readiness are assumed.

The jet from a punkah-louvre should be directed in such a way that no annoyance is caused to people in the vicinity, but the maximum flow must be maintained in order to keep up the rate of change of air in the compartment. The practice of fitting cloth filters to punkah-louvres should be discouraged, because the filters impair the air flow, especially when they become clogged with dirt, and so cause high internal temperatures and humidities.

Punkah-louvres operate correctly only within certain limits of air pressure in the trunking, and fitting additional home-made supply terminals may therefore impair the whole system. The fitting of home-made deflector plates to supply openings should not be permitted, nor should any tampering with the relief valves in the ventilation trunking be allowed.

Ventilation systems must be inspected and thoroughly cleaned out at regular intervals, say once every three months, otherwise their performance deteriorates considerably. Inspection plates and drain plugs are provided where necessary, and they should always be removed at the inspections. Routine cleaning is best effected by blowing through the whole system, section by section, with the ship's compressed air service. Certain systems are fitted with metallic gauze or fabric filters and these must be inspected and cleaned much more frequently if the ventilation system is to perform its task. Flameproof filters are extremely delicate, and must be handled very carefully to prevent damage.

CHAPTER 3

Types and Design of Merchant Ships

One of the chief justifications for the existence of men-of-war has always been the need to protect merchant shipping and to ensure that trade by sea can be carried on peaceably. In times of war the warships of each nation attempt to safeguard its own seaborne supplies and to disrupt those of its enemies. There is thus ample reason why a naval officer should be well acquainted with the types, design and functioning of merchant shipping generally.

There is such a wealth of types, however, that there is space in this chapter to describe in broad outline the main types only and the principal factors affecting their design and operation. H.M. ships should take every opportunity at sea and in harbour to make contact with merchant ships, and should cultivate a liaison with their officers and their various organisations whenever possible.

CLASSIFICATION OF MERCHANT SHIPS

In a very broad sense merchant ships can be classified in two ways:

1. as either *liners* or *tramps*,
2. as either *passenger* or *cargo* ships.

A *liner* is any ship which sails to schedule on a definite route for a specific destination, with advertised dates of departure from, and arrival at, specified ports of call along her route, and she can thus be a ship carrying passengers or cargo or both. The term, therefore, includes not only the ocean-going passenger or cargo liners, but also cross-Channel ships and some coasting vessels.

A *tramp*, as her name implies, is a ship which does not keep to a fixed route or sail to any particular schedule. She is usually purely a cargo vessel which is hired out by her owners under contract to a charterer who, by the terms of his contract, provides her with cargo and specifies her ports of call and the approximate dates of her arrival and departure. Her routes and ports of call are governed solely by the availability of suitable cargoes, and as these must vary considerably, both seasonally and geographically, she may roam over the oceans for a long time before returning to her home port.

The interests of passengers, as regards both safety and comfort, are protected by law, and any British ship which carries more than 12 passengers must have a passenger certificate issued by the Ministry of Transport; she can therefore be classed as a passenger ship, although she may carry cargo as well. To qualify for the certificate the ship must be surveyed annually and must conform to certain minimum standards for hull structure, watertight sub-division, lifesaving appliances, fire protection, firefighting and radio equipment. These standards are modified to a certain degree in vessels such as cross-Channel ships, coasters, ships engaged in the pilgrim trade, pleasure steamers and vessels plying in sheltered waters.

Sea-going ships which carry cargo and less than 13 passengers do not require

a passenger certificate and so need not conform to any legal structural standards except those laid down by the *Load Line Rules* (as described later in this chapter) for all sea-going vessels, and such ships can be classed as cargo vessels. They are, however, generally built to the minimum standards of construction laid down by the *Classification Societies* (as described later in this chapter) for purposes of insurance, and have to conform to certain minimum legal standards of accommodation and of lifesaving, firefighting and radio equipment.

TYPES OF MERCHANT SHIP

Within the broad classification already given one can distinguish the following well-established types:

Passenger liner

The *passenger liner* is usually designed for the transatlantic passenger trade between Europe and North America and runs to a strict schedule of times of arrival and departure at her terminal ports. Normally of 20,000 tons gross and above, more than 750 ft in length and with a speed of over 25 knots, the carrying capacity of these vessels is almost entirely devoted to passengers and their needs, but most carry mails and a small amount of cargo as well. An example of the upper limit of this type is the Cunard liner *Queen Elizabeth*, which has a gross tonnage of 83,673, an overall length of 1,031 ft, and a maximum speed of over 32 knots. A more recent example is the S.S. *United States*, of gross tonnage 53,000 and maximum speed 35 knots.

Passenger and cargo liner

The *passenger and cargo liner* is designed for the passenger and cargo trades between Europe and the rest of the world. Her voyage between her terminal ports is usually a long one and she may call at several ports along her route. The gross tonnage of such ships varies from 8,000 to 40,000, their length from 400 to 750 ft, and their speed from 13 to 25 knots. Their carrying capacity is divided between passengers and cargo, and they usually carry mails as well. Examples of this type are ships of the P. & O. and Orient line plying between England, Australia and the Far East, and of the Union Castle line plying between England and South Africa.

Cargo liner

The *cargo liner* is virtually an ocean-going cargo ship, but because she plies on a fixed route to an advertised schedule she usually has accommodation for a small number of passengers. Such ships are usually designed for the route on which it is intended they should ply and for the types of cargo they are liable to carry, and their size and type therefore vary considerably. Broadly speaking, however, they are between 2,000 and 20,000 tons gross, with speeds of between 14 and 20 knots, and between 200 and 600 ft in length. Most of them are designed to carry a general cargo, though they may occasionally carry bulk cargoes, and some are built to carry perishable commodities such as meat, eggs, dairy produce and fruit in refrigerated holds. The number of passengers has to be limited to 12 if the more rigorous passenger-ship construction rules are not to be invoked.

Examples of the type are ships of the Clan line carrying general cargoes between England, Europe, Africa, India and Australia; *refrigerator ships* of the Port line carrying chilled and frozen meat from New Zealand and Australia to England; and the *banana boats* of Elder and Fyffe's Ltd., carrying bananas and other fruit from the West Indies to England.

Tramp

Tramps are usually designed to carry bulk cargoes such as grain, clay, cement, nuts, salt, ores and bitumen, though they may also be chartered to carry a general cargo. Some of these ships can carry several types of bulk cargo, but others are designed for a particular trade, such as the ore ships which are specially fitted and strongly constructed for the carriage of this dense type of cargo, and colliers which often carry coal on the outward voyage and a different bulk cargo on the return voyage.

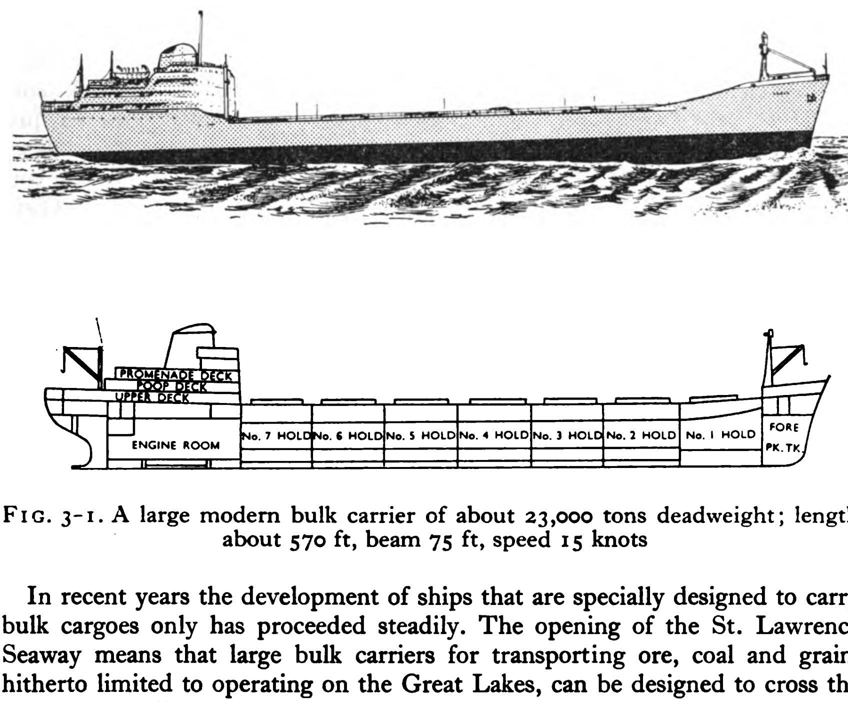


FIG. 3-1. A large modern bulk carrier of about 23,000 tons deadweight; length about 570 ft, beam 75 ft, speed 15 knots

In recent years the development of ships that are specially designed to carry bulk cargoes only has proceeded steadily. The opening of the St. Lawrence Seaway means that large bulk carriers for transporting ore, coal and grain, hitherto limited to operating on the Great Lakes, can be designed to cross the Atlantic as well. Ships to carry up to 47,000 tons deadweight of bulk cargo are being built. As with tankers, the tendency in these ships is to place the machinery, accommodation and navigation bridge right aft. A typical example of a modern bulk carrier designed to carry grain, coal or ore is shown in fig. 3-1.

Accommodation for passengers is not usually provided in tramps, because they seldom ply on a fixed route. The general-purpose tramps must be large enough to carry a worth-while amount of cargo and weather the storms of any ocean they may have to cross, and yet they must not be too large to enter the smaller ports of the world. For these reasons their gross tonnage is usually between 2,000 and 10,000. While speed is a desirable quality in a tramp, it

considerably increases her running costs, which must be kept as low as possible. Improvements in material, machinery, fuel and methods of construction, however, have enabled the designer to increase the speed of the average tramp from about 9 knots in 1910 to as much as 14–16 knots in 1963.

Tanker

Tankers are ships specially built to carry a liquid cargo in bulk, and they usually ply on a fixed route with few intermediate ports of call. They vary greatly in size, from the 2,000-ton coaster to the monster ships of over 100,000 tons deadweight. Their speed also varies greatly, from 10 to as much as 20 knots. Though plying on a fixed route, tankers are not usually provided with accommodation for passengers because of the highly inflammable nature of their cargo and the consequent risk of fire.

The operation of a tanker fleet differs greatly from that of a fleet of cargo liners. A tanker can very seldom get a return cargo, and it is therefore quite usual for her to discharge a full cargo, load with ballast, bunkers and stores, and sail on the return voyage within from 18 to 36 hours of arriving at her destination; and her turnaround at her loading port may not take much longer. A tanker therefore spends much less time in port than does a cargo liner, and her quick turnarounds considerably complicate the organisation for routine overhauls and running repairs, which in a cargo liner can be carried out during the comparatively long periods when she is in port loading or discharging cargo. Owing to the great risk of fire or explosion, moreover, no repairs which could cause parks can be undertaken in a tanker until she is entirely freed of inflammable or explosive gases. To run a fleet of tankers economically and efficiently, careful planning of all examinations, overhauls, periodical dry docking and surveys is necessary to ensure that each ship will be out of service for not more than one month annually at the most.

Coaster

Coasters are virtually small cargo liners built for the coastal trade of a country or for short sea voyages, such as those across the North Sea or the Channel, and some may carry a limited number of passengers. Their size is seldom greater than 3,000 tons gross and their speed is usually between 10 and 15 knots.

Short sea passenger liner

Short sea passenger liners (formerly known as *packets*) are small, fast vessels built principally for the passenger trade for short sea voyages, such as the cross-Channel services between England and France and England and Ireland, and the North Sea services to Belgium, Holland and the Scandinavian countries. They are usually owned by the British Transport Commission or by foreign railway authorities, sail to a strict schedule to link with the train services of the countries between which they ply, and they also carry mail and a small amount of cargo. Their size may vary from the 500-ton Isle of Wight steamers to the 5,000-ton cross-Channel ships; their speed may be from 10 to 25 knots, and they are usually of shallow draught and very handy for manœuvring in the confined and shallow ports between which they ply.

CARGO VESSELS

Of the various types of merchant vessel mentioned above it is intended to describe in more detail only two types, the conventional *cargo vessel* and the *tanker*. An outline of cargo stowage is given in Chapter 4; while further details of the safety arrangements in these ships, such as watertight sub-division, fire precautions and lifesaving equipment, are covered in Chapter 5.

Development of cargo vessels

The earliest type of cargo steamer was a *flush decker*, in which the openings above the engine and boiler rooms were surrounded by low casings fitted with skylights to admit light and air. Experience showed that this form of hull was

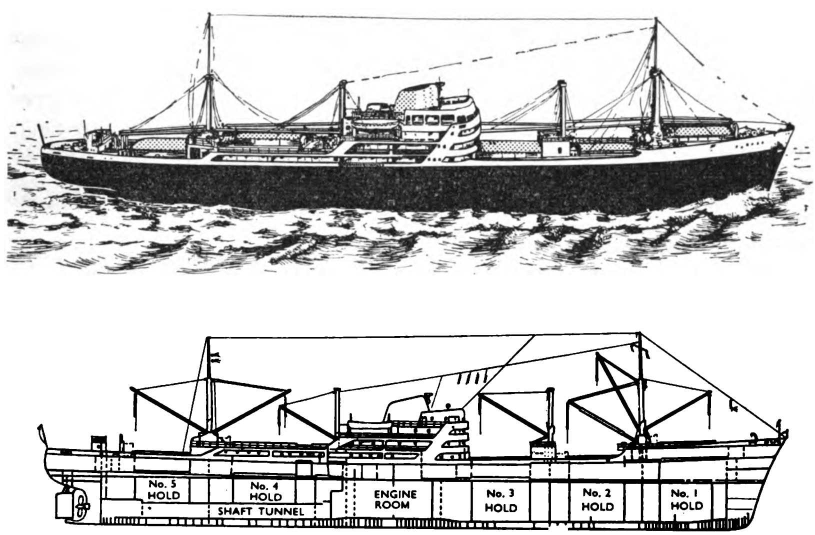


FIG. 3–2. A large modern cargo vessel of about 13,000 tons deadweight (9000 tons gross); length about 470 ft, beam 60 ft, speed 15 knots

dangerous, and so light superstructures extending from side to side of the ship were built round the machinery casings. A further development was the addition of a forecastle and poop, for improved seaworthiness, which in turn led to the well-known *three-island* type of cargo vessel with forecastle, bridge and poop superstructures, and before and abaft the bridge a well-deck protected by bulwarks and well suited for the carriage of deck cargoes such as timber. Variations of the three-island type are the *shelter-deck* ship, in which all three superstructures are extended to form a continuous non-watertight superstructure from bow to stern, thus providing a sheltered stowage which is not normally included in the net or register tonnage and is therefore exempt from harbour dues when no cargo is carried in the superstructure spaces; *well-deck* ships, in which the poop is extended to join the bridge; and the *raised-quarterdeck* ships, in which the upper deck abaft the bridge superstructure is raised a foot or so to provide more cargo space aft. A typical modern general-purpose dry-cargo shelter-deck vessel is illustrated in fig. 3–2.

Deep tanks

Many cargo liners are nowadays equipped with one or more *deep tanks*, which are situated amidships, extend the full width of the ship and have their tops usually level with the 'tween-decks'. These tanks serve the double purpose of enabling the ship to carry a part cargo of liquid in bulk and of improving her seaworthiness when in ballast or lightly loaded.

The capacity of these tanks varies from 500 to 2,000 tons deadweight, and they are usually divided longitudinally by one or more liquid-tight bulkheads into two or more compartments so that different liquids can be carried and the free-surface effect of the liquids be reduced. Their use is not, however, confined to the carriage of liquids alone; they can be used for carrying bulk cargo or general cargo, and for this reason they are fitted with large removable lids or hatches.

These tanks are particularly useful for water ballast when the ship is lightly laden, because when completely filled with sea water they give the ship the necessary degree of immersion without unduly lowering her centre of gravity. Ships which are not fitted with deep tanks and have all their ballast tanks in their double bottoms are liable to be unduly stiff when lightly laden, because all the weight is concentrated low down in the ship.

Cargo-handling arrangements

The size and weight of individual items of cargo which can be handled in a cargo liner depend on the size of her hatchways, the strength of her derricks and the power of her winches. The size of cargo hatches varies, but a length of 30 ft and a breadth of 20 ft are about average dimensions. The normal derrick provided has a maximum safe working load of 5 tons, and its winch should be capable of hoisting a load of one ton at a speed of 250 ft per minute. For loads of up to one ton the derrick is rigged with a whip or runner, but for greater loads it is rigged with a double whip or a purchase. Many ships are equipped with one, and sometimes two, heavy-lift or *jumbo* derricks; the maximum load they can lift varies from 10 to 30 tons. A few ships are specially constructed and equipped for extra heavy lifts of from 50 tons to as much as 180 tons; they are provided with special ballasting arrangements to ensure that they have the necessary margin of stability when hoisting heavy loads out or in. From two to four derricks, each with its own winch, are usually provided for each hold; and when working at full speed under ideal conditions about 20 tons of cargo per hour can be handled at each hatch.

TANKERS

Layout

Since 1945 the size of tankers has increased very considerably and few now built for the overseas trade are of less than 15,000 tons deadweight. Many approximate to 18,000 tons deadweight and some are of 35,000 and 65,000 deadweight capacity. The largest to date is able to carry 130,000 deadweight tons on a length approaching 1,000 ft, beam approximately 140 ft and draught 48 ft. The majority of the tankers recently built are propelled by steam turbine machinery.

The officers are accommodated in the bridge superstructure, and the crews' accommodation, galleys, wash-places and officers' smokeroom are in the after superstructure. This distribution lessens the risk of fire from indiscriminate smoking or from the galley fires. The machinery is situated right aft to minimise the danger of fire from sparks from the funnel and also to dispense with the long, oil-tight or spirit-tight shaft tunnel which would be necessary in a ship with her engines amidships.

It may well be that tankers, whilst retaining their characteristic of having the funnel aft, may also have the bridge incorporated in the after structure in future. This will allow a clear view of the whole of the tank deck. Such placing of all the accommodation and navigational equipment aft improves the safety of the crew. A typical modern tanker built on this principle is shown in fig. 3–3.

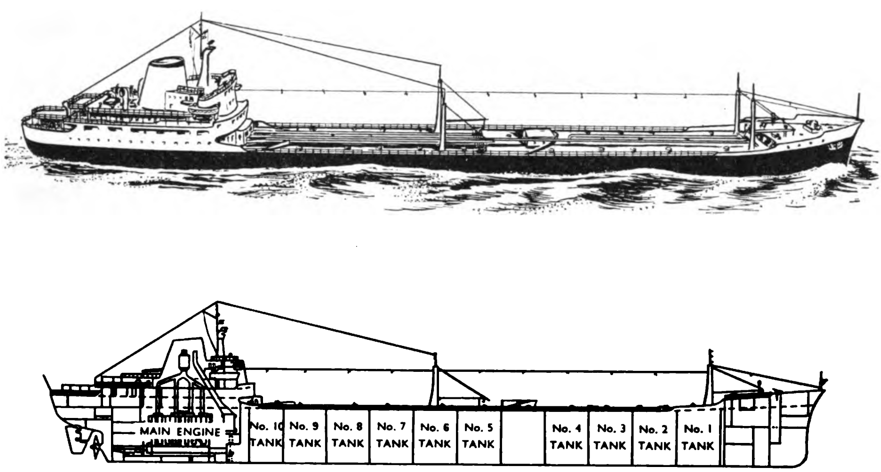


FIG. 3–3. A modern tanker of about 40,000 tons deadweight; length about 680 ft, beam 95 ft, speed 18 knots

Construction

The minimum freeboard allowed by the load-line regulations (described later in this chapter) for tankers is much less than that allowed for the ordinary cargo vessel, and the poop, bridge and forecastle of a tanker are therefore connected usually by a *fore-and-aft bridge* to allow the crew to pass from one island to another in safety when the ship is loaded to her marks in a seaway. This deeper loading is permitted for the following reasons:

1. The cargo hatches are very small, being used only for access and to admit light and air at certain times.
2. The hatch covers are made of steel, or alloy, are as strong as the deck plating, and are very securely fastened down by drop-bolts and wing-nuts to form a packed, oil-tight joint with the hatch coaming.
3. There are no large, open ventilators leading to the cargo compartments.
4. The ship is sub-divided into a larger number of watertight compartments than is an ordinary cargo vessel.

The fore-and-aft bridge also forms a convenient support for the numerous pipelines which run along the upper deck, i.e. the steam and exhaust lines, the steam-smothering line, the wash-deck line, the vapour line, and the oil-fuel-transfer line. In addition, there are the main electricity supply leads, telemotor pipes for the steering gear, and the telephone and telegraph leads.

The oil-carrying space is divided into tanks which are again sub-divided, usually making three tanks abreast, i.e. a rather large centre tank with small wing tanks to port and starboard. The common practice is to number the tanks from forward to aft, and the larger modern vessels may have twelve tanks or more, thus giving thirty-six cargo compartments in all. The oil-carrying space is separated from the forward and after sections of the ship by spaces called *cofferdams*, which are narrow compartments occupying the whole depth and beam of the ship. These cofferdams ensure complete segregation of the living quarters, machinery spaces and store rooms from the cargo tanks. No pipes, leads or fittings are ever allowed to pass through the bulkheads of a cofferdam. In an emergency they can be flooded.

Trim

As in any ship with her machinery right aft, a tanker's trim is difficult to adjust and control when loading and discharging, particularly when different grade cargoes have to be discharged at different ports. Another trimming problem is caused by the consumption of oil fuel on passage. This can be overcome by providing a deep tank for oil fuel right forward; as fuel in the cross-bunker situated immediately before the engine room is used, the bunker is topped up with oil transferred from the forward deep tank, thus lightening the bows.

Ballasting

When a tanker has discharged her cargo and sails empty she is ballasted by flooding sufficient tanks with sea water to give her the required trim and draught. However, some of the more modern tankers are fitted with permanent ballast tanks. This means that certain tanks, not used for cargo but required for buoyancy, can be utilised for ballast. It is usual when such a system is fitted for these tanks to be segregated as much as possible from the cargo system, and to have their own pump and lines, which are never used for oil. This allows for ballasting concurrently with discharging, or for deballasting while loading, thereby saving turnaround time. In very large tankers, the loading of ballast during the discharge of cargo reduces the stress and strain occasioned by the vessel being in a light (empty) condition.

Discharging

Most crude-oil carrying vessels have their pump rooms aft of the cargo spaces to allow a better drainage of the tanks. Usually four suction lines of about 16 inches in diameter are laid along the bottom of the vessel and so positioned as to divide the whole of the cargo-carrying space into four sections. Each suction line terminates in the pump room at its respective pump, and all the pumps together may have a discharging capacity of between 2,000 and 5,000 tons per hour. In addition to these main suction lines, smaller lines, about 6 or 8

inches in diameter, are also ranged along the ship's bottom with suction valves in each tank. The purpose of these lines with their separate smaller pumps is to strip the tank finally dry after the main pump has removed the bulk. Master valves may also be fitted, either between tanks or sections of tanks, to segregate different grades of oil should the ship be required to carry more than one grade. The arrangement of valves, pumps and crossover lines in the pump room enables the pumping system to discharge liquids overside or to make transfers within the various cargo compartments. Sea valves are also installed to allow sea water to be taken on board for ballast. The main and stripping suction lines (known as discharge lines) lead from the pumps to the deck manifolds, to which flexible hoses can be coupled to connect the ship's system to the shore pipelines. Approximately 280 valves are installed in a typical cargo system.

Pumps

The pumps installed for the handling of cargo may be all of one type, i.e. centrifugal or reciprocating, or they may be a combination of types, the most common practice being to have main pumps of the centrifugal type with reciprocating stripping pumps. This combination allows for a speedy bulk discharge and a better draining. The motive power for pumps is usually steam or electric. If electricity is used the motors and other electrical equipment are outside the pump room (usually in the engine room), with the pump shaft passing through sealed glands in the bulkhead. This safety precaution is necessary because of the possibility of explosive gases in the pump room.

To load the various tanks and sections it is unnecessary for the oil to pass through the pump room, since each deck line is connected by a loading drop line with its corresponding suction main at the bottom of the ship, so allowing various grades of oil to be loaded without fear of contamination, provided the master valves are tightly closed.

Loading

In modern tankers, when loading a cargo the air displaced by the incoming oil is carried through a group pipe system that carries the vapour up the masts and vents it at a safe height above the weather deck. Each outlet is fitted with a 'U' bend and a flame arrester. This closed pipe system is also used when discharging, air being drawn in at the masthead to replace the oil discharged. When a tank is loaded, an automatic ullage gauge records the quantity of oil in it in cubic feet, and by reference to special petroleum tables the quantity in tons can be established.

Heating cargo

To maintain the cargo at a required temperature, steam heating coils are fitted in the tanks, in most cases at the bottom; but for cargoes which have to be heated to a high temperature, such as bitumen (which requires to be maintained at a temperature of about 300° F), these heating coils may extend up the sides of the tank.

Cleaning tanks

Cargo tanks need cleaning, both at regular intervals, such as before drydocking, and also whenever there is a change in the grade of oil to be carried. Tanks are

washed by means of mechanical washing machines which are lowered into the tank. The revolving jets installed in the machine are operated by the force of the water used; and whether this water is hot or cold or has a solvent added depends on the nature of the oil last carried in the tank.

FACTORS AFFECTING DESIGN OF MERCHANT SHIPS

Each type of merchant ship has been evolved to meet the requirements of her particular trade, and her design has had to be subjected to certain restrictions which are imposed by law to ensure the safety of the ship, her passengers and her crew.

Among the many factors affecting merchant ship design are the nature of the cargo or the class of passenger to be carried, the maximum length of run between fuelling ports, the speed required, dock dimensions and depth of water in the ports and canals to be used, the conditions of climate and weather likely to be encountered, the first cost of construction, and operating costs.

In addition to meeting the owner's requirements, certain features of the construction of a merchant ship, and the extent to which she may be loaded, are subject to certain standards and restrictions which are imposed by law and by rules laid down by the Classification Societies.

It is legally compulsory for all except a few special types of merchant ship to carry permanent marks on each side of the hull indicating the maximum draughts to which the ship may be loaded in different localities at different seasons of the year. These *load lines* are determined by assigning in each case the minimum freeboard permissible, and this freeboard depends upon the ship's dimensions, type, and structural strength. The maximum permissible displacement of a ship, and thus the extent to which she may be loaded, is therefore limited by law.

Classification Societies, originally formed to meet the needs of marine insurance, have laid down certain rules which must be observed in the construction of ships classed with them, and it is authoritatively accepted that vessels built to the standards defined in these rules shall be considered to be capable of being safely loaded to the maximum draught prescribed. The rules specify the hull scantlings (i.e. standard dimensions for parts of the structure) and therefore virtually determine the minimum weight of the hull structure.

The difference between the maximum displacement allowed and the weight of the hull structure is the weight of the machinery, equipment, bunkers, water, stores, crew, passengers and cargo, and it is the designer's problem to allocate as much as is possible of this weight to earning capacity, i.e. to cargo and passenger-carrying capacity.

A further factor, however, which has to be taken into account is the effect on the general design of the ship of the dues which the owners will be required to pay for the use of harbours, docks, canals and other port facilities during the lifetime of the ship. By law all ships must be measured for *tonnage*, on which such dues are levied, and it is therefore a further problem of the designer to embody in the construction of the ship all those factors which tend to reduce the tonnage measurement as much as possible.

To summarise, it may be said that in endeavouring to give the shipowner a maximum carrying capacity, the ship designer is restricted by regulations in the following ways:

1. By having to provide for the safety and comfort of the passengers and crew. This is dealt with by the Ministry of Transport, which prescribes:
   a. the maximum draught, by the assignment of load lines;
   b. conditions regarding watertight bulkheads, and their spacing, in passenger ships;
   c. the detailed design and arrangement of lifesaving appliances;
   d. structural requirements for restricting the spread of fire, especially in passenger ships;
   e. the minimum standards for crew and passenger spaces;
   f. conditions for stowage of cargoes such as coal, grain in bulk, dangerous goods, inflammable or explosive materials or liquids, etc.;
   g. the minimum provision for radio installations.

   Further information on the equipment for fire precautions and lifesaving and the requirements for watertight sub-division is given in Chapter 5.

2. By having to ensure the safe transport of the ship and her cargo under the normal hazards of the weather she is likely to encounter during her voyage. To serve as a guide for insuring the ship and her cargo, vessels are usually classed according to the rules of the Classification Societies. The fact that a ship is classed is accepted by the Ministry of Transport as a guarantee that she is structurally sound and efficiently equipped for her service. If a vessel is not so classed the Ministry's surveyors make the initial survey and subsequently the periodical surveys necessary to ensure that she is maintained in a satisfactory condition.

3. By reducing the tonnage measurement in order to keep down harbour, dock and canal dues. (Methods of measuring tonnage are described later in this chapter.) The measurement for tonnage is carried out by surveyors appointed by the Ministry of Transport.

Classification Societies

The original society for classifying merchant ships according to their strength and seaworthiness was Lloyd's Register of British and Foreign Shipping. It was formed in 1760 by persons engaged in marine insurance, as an association for protecting their interests at a time when no standards of strength and seaworthiness were laid down by law. The British Corporation, a similar but smaller body, was founded in 1890 at Glasgow by shipowners and others with marine interests, but in 1949 it was amalgamated with Lloyd's Register. There are several other Classification Societies which publish register books and rules of construction; these are mainly used in foreign countries.

Minimum freeboards, the methods by which they are assigned and corresponding standards of strength have been agreed internationally in the Load Line Convention. They are laid down by law and, although legally they are administered by the Ministry of Transport, the assignment of freeboards has been delegated by the Ministry to certain Classification Societies for ships

classed with them. The activities of the Societies go further and include regular, detailed surveys of hulls and machinery during the lifetime of a ship, as well as during her building, and they also include the tests of materials.

Lloyd's rules for determining the scantlings for any member of a ship's structure are in the form of a series of tables in which the scantlings are given in relation to the main dimensions of the ship, e.g. her length, beam, draught and depth. These tables, being based on the Society's accumulated experience, ensure the production of a thoroughly reliable ship.

A ship built to the scantlings set forth in Lloyd's Rules for the draught required may be designated *100A* in the Register, and the figure *1* is added if the anchors, cables and hawsers are also as prescribed. Thus the designation *100A1* means that the ship and her equipment are in Lloyd's highest class. Ships of special type are similarly classed, as, for example, *Class 100A1 Oil Tanker*, *Class 100A1 Ore Carrier*, *Class 100A1 Trawler*; or *Class 100A1 for Vessels in Restricted Service*, e.g. cross-Channel packets, in which some relaxations of the normal rules for passenger-carrying vessels are permitted. There is also *Class A1 for Restricted Service*, for ships trading in specially sheltered waters such as harbours and estuaries. Vessels built under the Society's special survey are entitled to the distinctive mark of a Maltese cross in front of their classification character.

A steel-built vessel can only retain the classification assigned to her when she was built if she passes a special survey every four years, these surveys becoming progressively more exacting as her age increases. In addition, all vessels are subject to annual or occasional surveys when practicable.

Another classification required by Lloyd's is for the machinery, including main and auxiliary engines, boilers, essential appliances, pumping arrangements and electrical equipment. Subject to compliance with the Society's requirements, the letters *L.M.C.* (Lloyd's Machinery Certificate) are added to the Register, continuance of this classification being subject to periodical surveys as with the hull.

Load lines

With the exception of certain minor vessels, it is required by international law that all merchant ships shall comply with specified minimum requirements in regard to the height of their freeboard, in order to ensure the safety of life at sea. The freeboard for each ship is assigned according to certain rules to ensure that the ship will have a reasonable reserve of buoyancy, and it determines the maximum draught to which the ship shall be loaded. This draught is required to be marked on the ship's sides by a load line.

The methods employed in the assignment are given in a *statutory instrument* called *The Load Line Rules*, published for the Ministry of Transport by H.M. Stationery Office, which includes regulations governing the minimum standards of strength to ensure that the structure of the ship can withstand the stresses set up by the loading when she is floating at the prescribed maximum draught. Separate rules are laid down for tankers, sailing ships, and ships carrying deck loads of timber. Exceptional cases are dealt with individually.

To qualify for the minimum freeboard allowed by *The Load Line Rules*, a ship must be built to scantlings which comply with the highest standard of the

rules of certain Classification Societies or which comply with standards of strength laid down in *The Load Line Rules*. Most passenger liners, however, cannot be loaded down to the maximum draught permissible for their dimensions because of the limited space available for cargo, and they would be unnecessarily strong if built to these standards. Such ships can be assigned an increased freeboard, and an allowance can be made for the lighter loading by permitting lighter scantlings in the hull structure. The smaller freeboard allowed to tankers has already been explained.

The freeboard is measured from the uppermost complete deck in which are incorporated permanent means of closing all openings in those parts of the deck exposed to the weather. In flush-decked ships, and in ships with detached poop, bridge and forecastle superstructures, this is the upper deck. In ships with a continuous non-watertight superstructure (i.e. shelter-deck vessels) the freeboard is measured from the deck below the uppermost deck.

The amount of the freeboard assigned to a ship depends mainly upon her length; the longer the ship the greater must be her freeboard. Corrections are made to the standard freeboard appropriate to the ship's length in accordance with the ship's form, the extent and height of her superstructures, any excess or lack of sheer or camber, and the ratio of her length to her depth measured from her freeboard deck.

The assigned freeboard is measured, midway between the bow and stern of the ship, vertically downwards from the upper surface of the freeboard deck where it meets the ship's side. It is indicated by a circle bisected by a horizontal line which is commonly called the *Plimsoll mark*, and it is permanently marked by chisel or centre-punch on the ship's side and then painted over in white or yellow on a dark background or black on a light background. Additional lines known as load lines are similarly marked immediately before the assigned freeboard to indicate the minimum freeboards allowed in different seasons and localities, in fresh water, and in any other circumstances applicable to the ship, her trade or her route. Typical markings are shown in fig. 3–4 and described below.

S indicates the summer freeboard, and this usually corresponds with the assigned freeboard. It is often called *centre of disc*.

W indicates the winter freeboard, which is greater than the summer freeboard by a quarter of an inch per foot of the summer draught.

WNA indicates the winter freeboard for voyages in the North Atlantic, and is greater than the winter freeboard by two inches for vessels not exceeding 330 ft in length; for vessels over 330 ft in length the *WNA* freeboard is the same as the winter freeboard and therefore is not indicated. *WNA* is, however, marked on all tankers and is equal to *W* freeboard plus one inch for each 100 ft of length.

T indicates the tropical freeboard, and is less than the summer freeboard by a quarter of an inch per foot of the summer draught.

F indicates the freeboard in fresh water when loaded to the summer-draught, salt-water displacement.

TF indicates the freeboard in fresh water when loaded to the tropical-draught, salt-water displacement.

The localities and seasons to which the different freeboards apply are internationally agreed and are laid down in *The Load Line Rules*. The rules necessarily assume that any cargo or ballast is correctly stowed and distributed to ensure that the ship is seaworthy and has a sufficient margin of stability, and the responsibility for this rests with the master. The *Certificate of Approval* for the load lines assigned to a particular ship is issued by the Ministry of Transport or the Classification Society concerned, and it must be framed and displayed

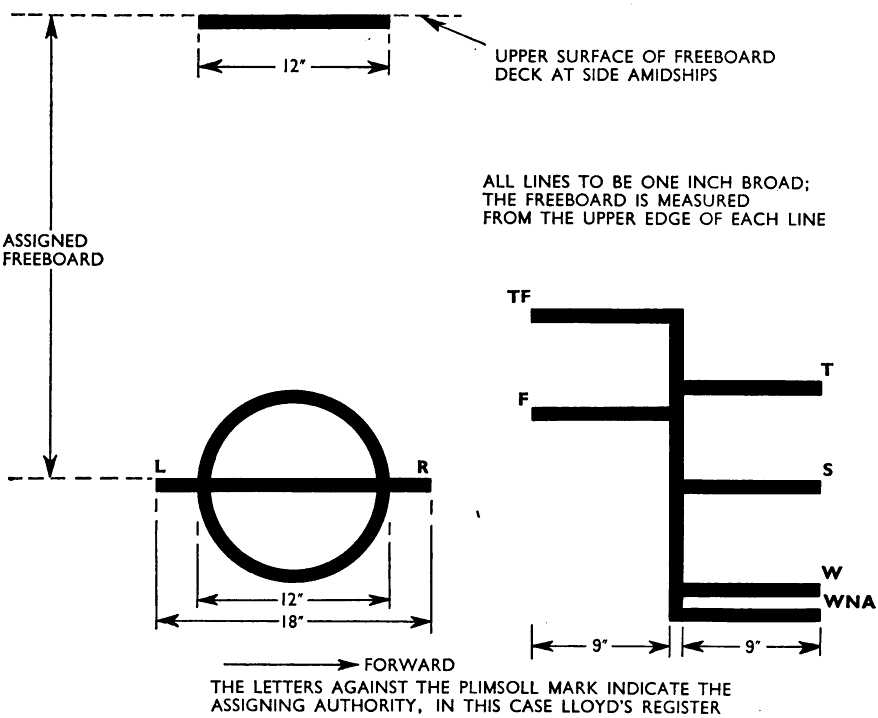


FIG. 3–4. Plimsoll mark and load lines

conspicuously in a public part of the ship. Before any ship puts to sea particulars of her actual draughts and freeboard immediately before sailing, together with the assigned freeboard, density of the water, fresh-water allowances, etc., must be entered in the ship's official log book. Methods of calculating changes in draught, trim, etc., are described in Chapter 1.

The assigned freeboard is checked annually by a surveyor of the Ministry of Transport or the Classification Society concerned, who endorses the Certificate accordingly in the space provided. The Certificate is valid for a period not exceeding five years, and before it can be renewed the ship must be completely surveyed.

International Conference on Safety of Life at Sea, 1960

Safety of life at sea has been the subject of a series of international conferences, i.e. in 1914, 1929, 1948 and 1960. British law at present (1963) incorporates the

agreed recommendations up to and including the 1948 conference, and may be expected in due course to be amended to cover those of 1960.

The 1960 conference expanded in some respects the constructional regulations of its predecessors, required the fitting of radio in smaller ships, permitted for the first time the use of inflatable lifesaving appliances and brought the rules for the carriage of bulk grain up to date. Some items formerly applying only to passenger ships will henceforth be applied to cargo ships as well. Further information on the safety arrangements in merchant ships generally is given in Chapter 5.

The problem of the safety of nuclear-powered ships was also considered for the first time, but only a few regulations were actually embodied in the International Convention which resulted from the conference. Further recommendations were included in an annex to the Convention, and these stress the importance of full incorporation in nuclear ships of all the safety features required in other types, on the basis that a casualty resulting from a 'conventional' cause, e.g. steering-gear failure, fire or collision, could endanger the power plant. The recommendations also give detailed guidance on the protection, enclosure and shielding of the nuclear plant; maintenance; manning; and the storage and disposal of radioactive waste.

TONNAGE MEASUREMENT

Every merchant ship is required by law to be measured during building for the assignment of her *tonnage*, and warships are also similarly measured. This tonnage forms the basis on which the appropriate dock, harbour and canal dues will be assessed, and is stated in terms of *tons* of 100 cubic ft.

Tonnage is supposed to have referred originally to the carrying capacity of a ship in *tuns* of wine, one tun having a capacity of 252 *wine* gallons and occupying about 42 cubic ft, but the present form of measurement was introduced by the Merchant Shipping Act of 1854. It is a measure of the internal volume of a ship in tons capacity, and must not be confused with *displacement*, which is the actual weight of the ship in tons weight. Although merchant ships are nearly always referred to by their tonnage—*gross*, *register* or *net*, and *deadweight*—warships are invariably referred to by their *displacement*; the displacement of a warship depends on her condition of loading (whether light, deep, etc.), and a figure commonly used nowadays is the *Standard Displacement*, which is the weight of the ship complete when fully manned and equipped with her stores and ammunition on board, but without her fuel and reserve feed-water. The figure for displacement is arrived at by computing the volume of sea water displaced, in cubic feet, and dividing by 35 to obtain tons.

The more important terms used in connection with the tonnage of merchant ships are explained below.

The *tonnage deck* is the upper deck in ships having less than three decks, and the second continuous deck from the bottom in other vessels.

Tonnage length is measured along the upper surface of the tonnage deck, from the inside of the frames or sparring at the stem to a similar point right aft.

Under-deck tonnage is the volume of the ship below the tonnage deck and measured to the inside of the frames or sparring, in tons of 100 cubic ft. In British tonnage measurement double-bottom spaces are not included, the depths for tonnage being measured to the upper side of the tank-top plating or the hold ceiling.

Gross tonnage is the under-deck tonnage plus the tonnage of between-deck spaces and all permanently closed-in erections above the tonnage deck which are available for cargo, stores or accommodation.

Net, or *register*, *tonnage* is the figure on which harbour, dock, canal and similar dues are assessed. It is obtained by deducting from the gross tonnage certain allowances for non-earning spaces, principally the propelling-machinery and steering-engine compartments, water-ballast tanks, cable lockers, accommodation for the officers and crew, and navigation spaces such as the wheel and chart houses.

Deadweight tonnage is the total weight of the cargo, stores, fresh water, fuel and crew which a vessel can carry when loaded down to her marks, and it is measured in tons weight.

Lightweight tonnage is displacement minus deadweight, i.e. the weight of the fabric of the ship.

Full details of the regulations for the measurement of tonnage, exempt spaces, and deductions for net tonnage are given in the pamphlet *Instructions as to the Tonnage Measurement of Ships*, published for the Ministry of Transport by H.M. Stationery Office.

For comparing the sizes of merchant ships, tonnage figures are not a reliable guide, because of the variations in the exemptions and deductions allowed for differences in details of their construction. The net tonnage is particularly misleading, and so sometimes is the gross tonnage, although it gives a fair idea of the bulk of a ship. A typical example is the open shelter-deck ship, so called because practically the whole of the between-deck space under the shelter-deck is regarded in British tonnage measurement as an *open* space, because there is at least one non-weathertight *tonnage hatch* in it. This space is therefore exempt from measurement, i.e. it is not included in the gross or net tonnage. A ship of the same dimensions without such an opening would have a considerably greater tonnage, because the exemption would not then apply.

To give some idea of how tonnage figures compare, those for a medium cargo steamship of standard construction and about 390 ft long would be roughly as follows:

Displacement	11,500
Deadweight	8,000
Lightweight	3,500
Gross	5,200
Net	3,200

Suez and Panama Canal tonnage

The principles governing the measurement of ships by the Suez or Panama Canal rules are the same as for British tonnage, but there are detailed differences as regards the exemption of certain spaces and the deductions allowed for net

tonnage. These tonnage figures often vary considerably from the British register tonnages, and usually work out as higher than them by the following percentages, roughly:

Suez: 5 per cent higher than gross
30 per cent higher than net
Panama: 10 per cent higher than gross
30 per cent higher than net

Tonnage of warships

All H.M. ships are measured by the Ministry of Transport for tonnage in accordance with both the British and Suez Canal rules, a copy of the tonnage certificate being kept on board in the *Ship's Book.* An important difference between men-of-war and merchant ships is that no deduction for crew spaces is allowed in the net tonnage of the former. By agreement between the Admiralty, the tonnage-assigning authority and the harbour authorities, the dues to be paid by the Admiralty for the use of British docks and harbours by H.M. ships are based on the legal net tonnage, reduced by seven per cent of the gross tonnage to allow for crew spaces. This special tonnage figure is inserted on a slip attached to the tonnage certificate.

In the Suez Canal a crew- and navigation-space deduction, limited to five per cent of the gross tonnage, is allowed to men-of-war. Double-bottom spaces are not included in the tonnage, but must be paid for in passing through the canal if they contain more than six inches depth of oil fuel; they are then paid for on their full capacity.

In the Panama Canal, men-of-war are assessed on their actual displacement. Curves of displacement and tons-per-inch-immersion are included with the Statement of Stability kept in the *Ship's Book.*

REGISTRATION

British ships are required to be registered and provided with a *Certificate of Registry* issued by the Ministry of Transport and carried on board. This certificate gives essential particulars of the ship, such as the identification dimensions, gross and net tonnages, name, port of registry, place and date of build, description, particulars of displacement, particulars of machinery, builder's name, and name and address of owners.

Certain conditions are by law required to be complied with before a ship can be registered. These include the marking of the approved name on each bow and on the stern; the marking of the port of registry on the stern; the certification of draught marks at bow and stern; and the permanent cutting-in of the official number (which is never altered once the ship is registered) and the register tonnage on the main beam of the ship.

CHAPTER 4

Cargo Stowage

The efficient, economical and safe stowage of a shipment of cargo is a complex problem which needs a thorough knowledge and considerable experience of the subject. This chapter is intended only to explain the principles and main features of cargo transportation. Various textbooks on this subject have been written, of which *Stowage*,* by Captain R. E. Thomas, is generally recognised by the British Merchant Navy as the leading authority on the subject, and the reader is advised to consult this book when confronted with a particular stowage problem.

GLOSSARY OF TERMS

Apron, the quayside between a shed and the edge of a quay.

Backweight (or *Deadman*) *rig*, a rig used largely in the U.S.A. with a swinging derrick to return it to a position plumbing the hold after it has hoisted out a load. A lazy guy is shackled to the derrick head, then rove through the head block of another derrick rigged to plumb the opposite side of the hold, and a suitable weight is slung on its end. (See fig. 4–1.)

Bale capacity, the cargo space available within a ship or a hold, measured in cubic feet from the lower edges of the beams and the inner edges of the cargo battens across the side frames. It is therefore less than the grain capacity (which see) by the amount of space between the beams and the frames.

Between deck, see *'Tween deck*.

Bilge and cantline, the method of stowing barrels or casks with the bilges of the casks of the upper tiers over the cantlines of the casks of the lower tiers. (See fig. 4–5.)

Bill of lading, a receipt for goods loaded in a ship. It gives the terms on which the goods are accepted as freight, and is signed by the person who contracts to carry them or his representative (e.g. the master of the ship). Although primarily a receipt, a bill of lading is also treated as a negotiable document of title representing the goods to which it relates.

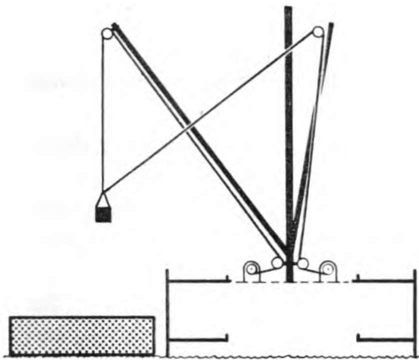
Booby hatch, a small additional hatchway giving access to a hold.

Breaking-out, the operation of breaking bulk in a hold when starting to discharge cargo.

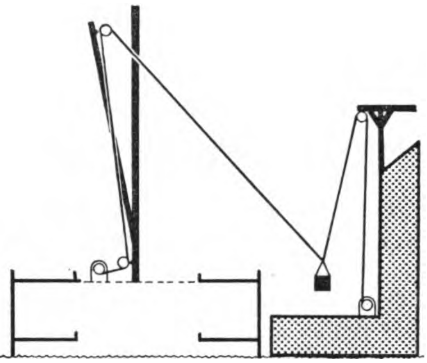
Breaking bulk, shifting the first few packages in a closely-stowed hold, the better to get at the remainder.

Broken stowage, the spaces between items or parcels of cargo when stowed in a hold. It may be due to bad stowage, irregular sizes or shapes of the various items of cargo, the size and shape of the hold, stanchions and similar fittings in way of the cargo, or the need to use a lot of dunnage. An arbitrary

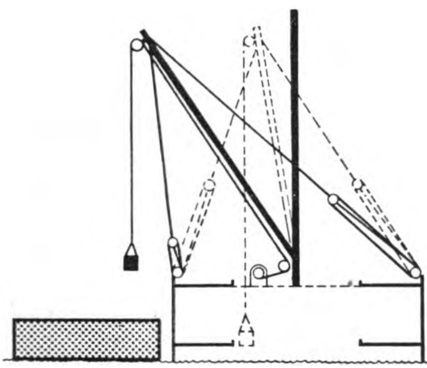
* Published by Messrs. Brown, Son and Ferguson, of Glasgow.



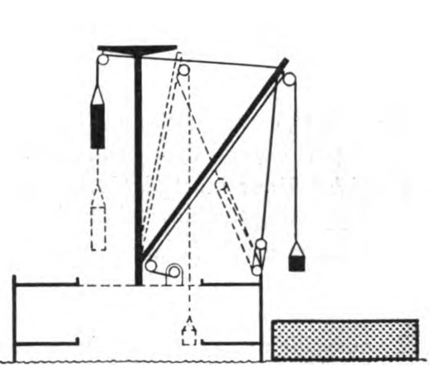
STANDING DERRICKS—UNION PURCHASE
USUAL METHOD FOR LOADING AND DISCHARGING



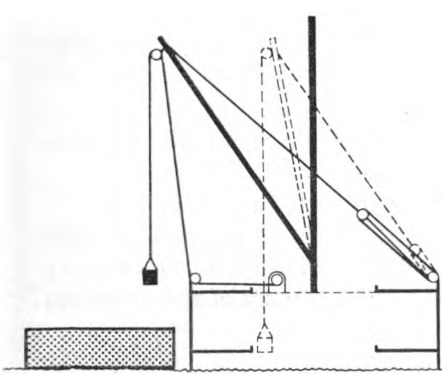
STANDING DERRICK —HOUSE FALL
USED WHEN ONE DERRICK AND ONE WINCH ONLY ARE AVAILABLE IN SHIP FOR LOADING OR DISCHARGING



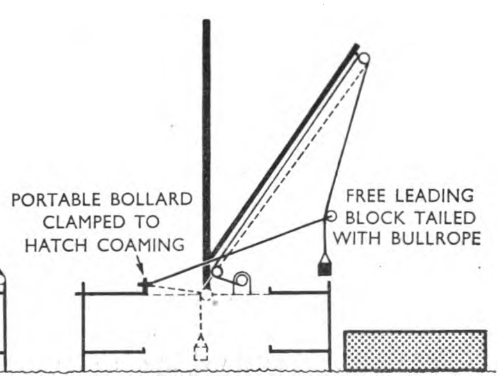
SWINGING DERRICK
USED FOR LOADING AND DISCHARGING WHEN ONE DERRICK AND ONE WINCH ONLY ARE AVAILABLE IN SHIP



SWINGING DERRICK WITH DEADMAN
USED FOR DISCHARGING—DEADMAN RETURNS LIGHT DERRICK OVER HOLD



SWINGING DERRICK WITH WING LEAD
USED FOR DISCHARGING—LEAD OF RUNNERS TO BULWARKS SWINGS DERRICK OVER SIDE



STANDING DERRICK—LIVERPOOL RIG
USED FOR DISCHARGING—BULLROPE TAILED TO LEADING BLOCK USED TO GUIDE HOIST CLEAR OF HATCHWAY

D

FIG. 4–1. Various derrick rigs

allowance for broken stowage, based on experience, is made when planning the stowage of different types of cargo in the same hold.

Bulk cargo, any type of dry or liquid cargo such as grain, coal, ores and petroleum which can be stowed in bulk.

Bullrope, a rope for hauling cargo from the wings or ends of a hold to its centre or *vice versa*; or a rope used as a steadying line to guide a lift clear of obstructions in its path.

Cargo battens, removable wooden battens fitted across the inner edges of the frames in a hold to prevent contact between cargo of a general nature and the ship's side. In addition to protecting the cargo from damage by sweating of the ship's sides, they provide an air space for ventilation.

Cargo deadweight, the weight in tons of an item, or parcel, of cargo.

Ceiling, the wooden deck fitted over the bottoms of the holds of some ships which carry a general cargo. Its purpose is to prevent contact between the cargo and the inner bottom or the tank tops.

Cordwood, small pieces of wood used as dunnage.

Deadman rig, see *Backweight rig*.

Demurrage, compensation paid to the owner of a vessel which has been delayed in port beyond the agreed time.

Derrick table or *Mast platform*, a tabernacle built round the foot of a mast for supporting the heels of the derricks and occasionally the winches.

Despatch money, a bonus paid by the shipowner to the charterer if his ship is loaded or discharged before the period agreed upon.

Drift, the clearance between the head block of a derrick and the bulwarks, the quayside or any obstruction in its path.

Dunnage, baulks of timber, quartering, planks, cordwood and other similar materials, used for shoring, chocking, packing and ventilating cargo.

Fiddley, the space above the boiler and engine rooms of a ship.

Flooring-out, spreading dunnage or stowing cargo over the bottom of a hold.

Full and down, describes the condition of a vessel when her holds are filled to capacity and she is loaded down to her maximum legal draught.

Gantry, an overhanging or spanning structure.

General cargo, a cargo comprising different commodities, as distinct from homogeneous cargo such as grain or liquids in bulk.

Gin fall, another name for the whip, runner or purchase of a derrick.

Grain capacity, cargo space available within a ship or a hold, measured in cubic feet from the sides of the ship and the deckheads of the holds. It is therefore greater than the bale capacity (which see) by the amount of space between the frames and the beams.

Gross weight, the total weight of a case and its contents.

Hand hook, a pointed steel hook with a T-handle used by stevedores for handling cargo. Its use should be strictly confined to handling crates, cases and other similar articles, and it should never be used for handling bales, bags and other 'softly'-packed goods.

Hatch beams, removable steel beams fitted athwart a hatch to strengthen it and to support the hatch boards.

Hatch boards, stout timber boards which fit over the hatch beams and form part of the hatch cover.

Hatch square, the area enclosed by the coamings of a hatch.

Hoist or *Sett*, one or a number of items of cargo slung for hoisting.

Homogeneous cargo, a cargo comprising one commodity.

House fall, a variation of the union purchase rig in which one of the whips is led through a head block shackled to a structure on shore. (See fig. 4–1.)

Jumbo derrick, a derrick designed for heavy lifts.

Lay days, the period agreed upon between a charterer and a shipowner for loading or discharging a shipment of cargo. (See also *Demurrage* and *Despatch money*.)

Lazaret, a store room for a ship's stores or provisions, usually situated in the after part of the ship.

Limber boards, removable boards between the sides and bottom of a hold to give access to the bilges for cleaning or drying them out.

Liverpool rig, a rig used with a single standing derrick rigged to plumb over the ship's side. The hoist is guided through the hatch by reeving the whip through a tail block fitted with a bullrope, the bullrope being worked from a portable bollard clamped to the hatch coaming. (See fig. 4–1.)

Lock-up or *Locker*, a cargo space specially built or partitioned-off from a hold and situated usually in one of the lower or upper 'tween decks, where valuable cargo or cargo of a pilferable nature is stowed.

Lower hold, the lowest of a tier of holds in ships fitted with one or more 'tween decks.

Manifest, a detailed list of a ship's cargo, prepared at the port of shipment; it shows the marks, numbers and descriptions of packages, together with the names of the consignees.

Married gear, see *Union purchase rig*.

Mast platform, see *Derrick table*.

Midship derrick, the derrick which plumbs the hatch in the *Union purchase rig* (which see).

Midship guy, the guy rigged between the heads of the midship and outboard derricks.

Nett weight, the weight of the contents of a case or container.

Optional cargo, cargo of a general nature which, at the option of the consignor, may be discharged at any one of a number of ports.

Over-carriage, the carriage of cargo beyond its port of destination by an oversight.

Outboard (or *Yard-arm*) *derrick*, the derrick which plumbs over the ship's side in the *Union purchase rig* (which see).

Pallet, a wooden tray used for slinging a number of items of cargo in one sett.

Parcel, a number of items of cargo from a common source, or for a common destination.

Pontoon (or *Slab*) *hatch-cover*, a steel hatch-cover unsupported by beams.

Port speed, the rate at which cargo is loaded or discharged at a particular port. For bulk cargo it is sometimes called the *custom of the port*.

Quartering, timber of square cross-section used as dunnage.

Runner, the whip or fall of a derrick.

Save-all, a net rigged to catch any cargo falling between the ship and the quay, or a canvas sheet spread in a hold or on deck to catch any leakage from bagged cargo such as grain.

Separation, the stowage of one type of cargo apart from another as a precaution against fire, and for the prevention of contamination or deterioration of the cargo and damage to the cargo or the ship.

Sett, see *Hoist*.

Shipping ton, a measurement of 40 cu. ft used at the option of the ship owner in determining the freightage dues for cargo; it is approximately the space occupied by a ton of well-stowed Welsh coal. The freightage of heavier cargo is computed on its deadweight.

Short-landing, failure to discharge the whole of a cargo at its destination, due to an oversight. (See also *Over-carriage*.)

Sparring, planking or other material fitted as a lining to the sides or ends of a compartment to insulate the cargo from the sides or bulkheads.

Special cargo, fragile or valuable cargo which is consigned to the special custody of the Chief Officer, and stowed usually in the locker or other secure stowage.

Standing derrick, a derrick rigged to plumb one position only.

Stevedore, strictly, the person who contracts for the handling of cargo into or out of a ship. In general, however, men actually engaged in stowing or discharging the cargo are called stevedores.

Stowage factor, the volume in cu. ft occupied by a well-stowed ton (weight) of any particular type of cargo. It includes allowances for broken stowage and any dunnage required for that particular type of cargo.

Stowage plan, a rough plan of the ship showing the stowage of her cargo.

Strong-room, a strongly constructed, fireproof compartment, provided in some ships for the stowage of very valuable cargo or specie.

Supercargo, short for Cargo Superintendent—an official formerly appointed to a cargo ship by the shipowner or charterer expressly for the supervision of the loading, selling and discharging of her cargo and obtaining other cargoes; he sailed with the ship throughout her voyage. This office is seldom, if ever, filled nowadays.

Swinging derrick, a derrick rigged to plumb alternately over the hold and over the ship's side. (See fig. 4–1.)

Tally and *Tally clerk*. To tally is to check each item of cargo as it is loaded or discharged, and a tally clerk is the man who does this job.

Tare weight, the weight of an empty case or vehicle.

Tomming, shoring cargo to prevent it from shifting.

'Tween deck, an auxiliary cargo deck below the upper deck. In a hold with two 'tween decks the spaces are called the upper and lower 'tween decks and the lower hold.

Ullage, the amount by which a cask, tank or other container holding liquid is not full.

Union purchase rig or *Married gear*, a rig in which the whips of two standing derricks are joined to the cargo hook. One derrick plumbs the hold and the other plumbs over the ship's side. (See fig. 4–1.)

Wharfinger, the owner of a wharf with certain responsibilities in regard to goods stowed thereon, the upkeep of the wharf and of the berths alongside it.

Wing lead, an alternative to the backweight method (which see) of rigging a swinging derrick. The whip is led from the head of the derrick through a leading block on the ship's side and thence to the winch. As the whip takes the weight of a hoist the derrick will tend to swing over the ship's side. (See fig. 4–1.)

Winging, stowing cargo so that most of it is distributed in the wings of the hold. This may be done when stowing heavy items of cargo to improve the seaworthiness of the ship.

PRINCIPLES OF STOWAGE OF GENERAL CARGO

General planning

The aim in planning the stowage of a shipment of cargo is to achieve the condition of full and down, but with a general cargo this is seldom possible, because in doing so the planner must fulfil many different and often conflicting requirements. These requirements are: ensuring the necessary stability and trim of the ship throughout the voyage; ensuring that the cargo to be discharged at each port is easily accessible without having to restow the remainder; ensuring that it can be discharged as rapidly as possible; and seeing that those types of cargo which, owing to their nature, must not be adjacent to each other are well separated.

Provision of cargo

Most shipping lines employ agents at the major ports visited by their ships, to advertise for cargo and arrange for its delivery. The shipowner advises his agents well beforehand of the dates of arrival, loading and departure of each ship and also of her destination and route, and the scheduled and optional ports of call on the voyage. The agents then advertise this information among those shippers and others who are known to be interested in the trade along the proposed route, and ask them for details of any cargo they may have for shipment. These details are forwarded by the agents to the shipowner, who then starts to apportion the cargo and plan its stowage.

Ship's plans

The plans of a ship should include the following details essential to the cargo planner:

1. the grain and bale capacities of each hold;
2. the deck areas of holds and hatch squares;
3. upper deck areas available for deck cargo;
4. the dimensions of hatches and the number and capabilities of the derricks;

5. the cargo deadweight of the ship;
6. the deadweight of the ship when light, i.e. with stores, fuel, fresh water crew and ballast on board, but no cargo;
7. the draughts of the ship in the light condition;
8. the draughts of the ship when she is loaded to her maximum permissible seasonal draught;
9. stability data, such as cross curves of stability, hydrostatic curves and trim tables. (The use of these data is explained in Chapter 1.)

Particulars of cargo

The details of each item of cargo, or of a parcel of similar items, should include:

1. the overall dimensions and nett weight of each item;
2. the number of packages of the same nature in any one parcel;
3. the consignor's and consignee's names and addresses;
4. the marking on each item or batch.

Dunnage

The kind, quantity and total weight of dunnage carried will vary considerably with the nature of the cargo carried. If particularly heavy items are to be stowed in the 'tween decks or as deck cargo, the decks may have to be shored from the lower hold upwards and each item may require a considerable amount of tomming. Sometimes a temporary 'tween deck may have to be built in a deep lower hold when heavy cargo has to be stowed over crushable cargo, or a temporary bulkhead may have to be built to separate bulk cargo from general cargo. Bins may have to be constructed to protect deck cargo; and if there is much of it, catwalks may have to be built over it to give access forward and aft. These are, however, exceptional cases, and the dunnage usually consists of baulks, planks and quarterings of timber, cordwood, matting, cloths and rope, amounting in all to between about 100 and 200 tons deadweight in a ship of 7,000 tons gross.

The dunnage deadweight must, of course, be subtracted from that of the ship's cargo when assessing the cargo deadweight available, and similarly an allowance must be made for it when assessing the ship's available cargo capacity.

Broken stowage

The stowage factor for any particular type of cargo includes an allowance for broken stowage, but this allowance applies to that type of cargo alone and does not allow for broken stowage which may result from stowing that particular cargo with other kinds of cargo in the same hold. An allowance must also be made for broken stowage due to the shape of the holds and to pillars and similar fittings in way of the cargo. Furthermore, the stowage factor for a particular cargo may vary from port to port according to the way in which it is packed and the way in which it is stowed by the local stevedores. The planner must therefore make an arbitrary allowance for broken stowage, based on his experience of the various kinds of cargo and the skill of the stevedores at a port. This allowance may vary from 10 per cent to as much as 25 per cent of a ship's bale capacity.

The following examples show the wide differences between the stowage factors of different types of cargo:

Commodity	*Packaging*	*Stowage Factor*
Antimony	cases	20
Bran	bags	100–130
,,	bales	80–85
Cotton	bales	50–135
Granite	blocks	16–18
Hay	bales	90–105
Pig-iron	ingots	12–15
Rubber	cases	65–70
,,	bags or bales	40–50
Sugar	bags	40–50
Tea	chests	96–120
Tin	ingots	8–10
Tinned fruit	cases	60
Tyres	loose or bales	140–200
Wool	bales	40–240

SEPARATION OF CARGO

The segregation of cargo is necessary in order to prevent one kind from contaminating or damaging another, to minimise the risk of fire or explosion, to ensure that the ship has the required degree of stability, to provide necessary ventilation, to ensure the accessibility of cargo at its port of discharge, to avoid having to restow cargo, and to ensure that it can be discharged quickly and efficiently.

Contamination and tainting

Some commodities are very susceptible to tainting by moisture or odours, and others are very liable to leak or to produce moisture, odours or noxious gases. Examples of the former are flour, sugar, eggs, cheese, tea and pepper, and of the latter potatoes, onions, green vegetables, fruit, wine, grain, wet hides, manure, copra and freshly-sawn timber. Other goods are liable to be damaged or to deteriorate if placed in contact with certain other goods, or even near them, examples being iron and bagged chemicals, cotton and rubber, cotton and coke, cotton and oil, and chrome and manganese ores. Other commodities, again, are susceptible to spontaneous combustion if not properly ventilated, and some will produce moisture or noxious vapours if placed next to a hot bulkhead such as that of a boiler room or engine room; examples are copra, nuts, bay, wool and grain.

Some of these goods can be carried in the same hold if separated by stowing dry goods over wet goods, or by stowing them at opposite ends of a hold, or some in the 'tween decks and others in the lower hold. Some kinds of cargo, however, must be stowed in different holds, and in rare cases they may have to

be stowed at opposite ends of the ship, examples being frozen meat and fruit, and explosives of different types.

Crushing and chafing

Fragile goods may be crushed if overstowed with heavy cargo, or if stowed in too many tiers without separating them with dunnage, or if there is insufficient vertical separation with dunnage so that cargo in the wings is crushed as the ship rolls. Chafing is caused chiefly by bad stowing, which allows adjacent items of cargo to rub against each other with the movement of the ship. All of these, except overstowing, are mainly the concern of the stevedores and the ship's officers, but the planner can assist to a certain extent by providing what is called *filler cargo*, consisting of small packages of suitable goods which can be stowed between largely different kinds of cargo, and so enable the holds to be stowed compactly, symmetrically and evenly. Examples of filler cargo are bones, cordwood, bundles of wood and matting, rubber tyres, and coconut husks; such goods are usually accepted at a lower rate of freight on the understanding that they may be used as filler cargo, but on no account should they be used as dunnage to chock or separate the cargo.

Dangerous goods

Some explosive, highly inflammable, or corrosive goods are classed as *dangerous goods* and their stowage is regulated by law. Many kinds of dangerous goods must be carried as deck cargo and be stowed apart from each other in places where any fumes from them will not be drawn into the holds or living quarters, examples being drums of acid and cylinders of compressed, inflammable gases. Other goods, such as explosives, fireworks and matches, may be stowed below, but in specially-built, well-ventilated magazines, or in the 'tween decks well clear of other cargo. Other goods of this nature, such as petroleum products in drums, may be stowed in the lower holds, but special precautions must be taken to provide adequate ventilation and a cool temperature. Precautions must also be taken against fire or explosion *after* dangerous goods have been discharged.

Stability and trim

Separation of the cargo to provide the required degree of stability and trim both at the start of, and throughout, a voyage is most important. Account must be taken of the consumption of fuel, stores and water between ports of call, the discharge of part-cargoes at intermediate ports of call, and sometimes the minimum depths of water which the ship may encounter at any port. The stowage should be arranged so that the ship will have the required degree of stability between one port and the next without having to take in or discharge ballast while at sea, any necessary ballasting being carried out before the ship sails or while she is in sheltered waters. This is important, because many losses have been attributed to attempts to improve a ship's stability by ballasting while she was in a seaway.

If a ship is filled to capacity with a general cargo entirely for one destination, and provided that the stowage factors of the different types of cargo are not particularly high or low and the ship is not very stiff or tender, the shape and

size of her holds and the necessity for stowing light cargo over heavy cargo will usually ensure that on sailing she will have the required degree of stability and trim. If, however, the ship is bound for several intermediate ports of call, the various part-cargoes must be distributed throughout the holds and stowed symmetrically, both fore-and-aft and athwartships. If some of the cargo is particularly heavy, it must be distributed among the holds to avoid any exceptional shearing stresses, and also be divided between the lower holds and the 'tween decks so that the ship is neither too stiff nor too tender (see Chapter 1). The 'tween decks must never be overloaded.

Many British ships are provided with a Ralston's Stability Indicator. This is virtually a pivoted model of the ship which, when weights representing the deadweight of the cargo are added, shows the stability, draught and trim of the ship when loaded.

Accessibility

It is essential that cargo should be readily accessible on arrival at the port of its destination, so that there will be no delay in discharging it and no wasted time and expense in having to restow any other cargo which may be in the way. Cargo is usually stowed in the reverse order to that in which it will be discharged, to prevent the possibility of overstowing a cargo destined for an early port with the cargo consigned to a later port. The 'tween decks and hatch squares are very useful for separating cargo for accessibility, but the hatch square of the upper 'tween decks should always be reserved for cargo destined for the first port of call.

Optional cargo consigned for discharge at two or more ports is the most difficult to stow, particularly if there are several parcels of it. One way of dealing with it is to stow it in the upper 'tween decks in blocks spaced apart from one another, each reaching from the hatch square to the ends or the wings or the bulkheads of the 'tween deck.

Speed of handling

The planner must ensure that the cargo is stowed so that it can be discharged as quickly as possible. Any large quantity of cargo destined for a particular port should therefore be distributed evenly among as many holds as is practicable, so that each hold can be used simultaneously when loading or discharging. For the same reason the cargo should be stowed at the opposite ends or sides of each hold so that two gangs of stevedores can work in the hold at the same time without getting in each other's way.

When two or more cargoes each destined for a different port are stowed together in the same hold their stowage must be arranged so that discharging one will not necessitate restowing the remainder. The stowage of such cargoes should therefore be stepped down so that if one or more is discharged the remainder is stable and can easily be prevented from shifting with dunnage.

Examples of good and bad stowage are shown in fig. 4–2, and explained in the following notes.

1. In No. 1 hold cargo for the second and third ports has been stowed in the 'tween deck at the opposite end to its counterpart in the lower hold, thus enabling it to be discharged by two gangs working simultaneously. In No. 2 hold this would not be possible.

2. In No. 1 hold cargo for the second and third ports has been stepped down to avoid having to restow it after discharging the cargo for the first and second ports. In No. 2 hold cargo for the third port would have to be restowed after cargo for the first and second ports had been discharged.
3. In No. 2 hold it will be very difficult to handle the heavy cases when discharging them because of their stowage position. These should have been stowed at the bottom of the hold, where they would be dealt with last of all.
4. In No. 2 hold the N.A.A.F.I. supplies, which are not usually of a robust nature, have been overstowed by heavy iron pipes, which will probably crush them.

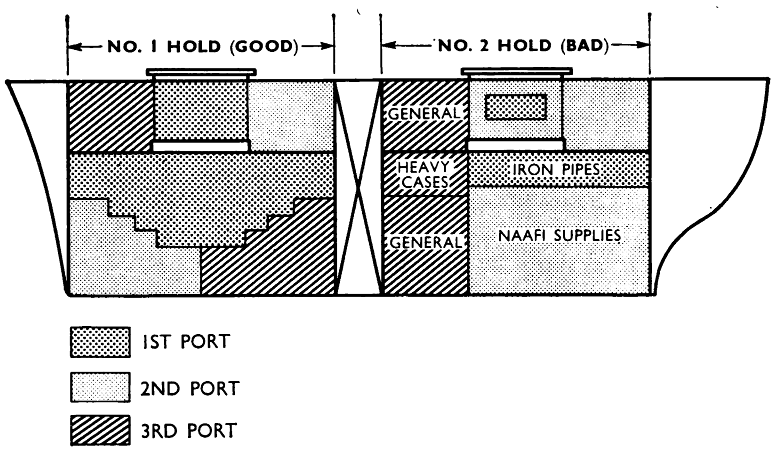


FIG. 4–2. Correct and incorrect methods of cargo stowage

PLANNING STOWAGE OF A GENERAL CARGO

Capabilities of the ship

The first stage in planning a stowage is to consider the features and capabilities of the ship and tabulate them in detail thus:

Deadweight

	tons
light ship	2,476
fuel	1,246
fresh water	320
stores	190
ballast	150
dunnage, say	100
departure state	4,482
maximum seasonal displacement	10,725
maximum cargo deadweight	6,243 tons

Bale capacity

	cu. ft
locker under forecastle	8,000
No. 1 hold 'tween deck	22,830
lower hold	51,110
No. 2 hold 'tween deck	37,030
lower hold	74,610
No. 3 hold 'tween deck	30,930
lower hold	58,010
No. 4 hold 'tween deck	27,100
lower hold	52,440
Total under-deck stowage	362,060 cu. ft

Deck stowage (estimated)
deadweight, 500 tons
capacity, 30,000 cu. ft

Stowage factors

under-deck: $\dfrac{\text{bale capacity}}{\text{cargo deadweight, less dunnage}} = \dfrac{362{,}060}{6{,}143} = 59$ (approx.)

full and down: $\dfrac{\text{total capacity}}{\text{total cargo deadweight}} = \dfrac{392{,}060}{6{,}243} = 63$ (approx.)

Operational data
normal full speed, 11 knots
average daily consumptions:
fuel, 13 tons
fresh water, 5 tons
stores, ½ ton

Draughts
before loading: forward, 10 ft 4 in.
aft, 15 ft 8 in.
mean, 13 ft 0 in.
maximum seasonal: 26 ft 3 in.

Derricks and hatches
four hatches, each 20 ft × 30 ft
eight 5-ton derricks, two to each hatch; maximum load 30 cwt when rigged with single whip
two jumbo derricks: No. 2 hold, 30-ton
No. 3 hold, 15-ton

Special stowages
strong room: capacity, 1,000 cu. ft

Break-down of cargo

The second stage is to tabulate the shipment under the headings of *deadweight and capacity*, *heavy cargo*, *fragile cargo*, *filler cargo*, *optional cargo*, *special cargo*, *dangerous goods*, *deck cargo*, *cargo requiring special separation*, *heavy lifts*, and *ports of loading and discharging*.

In the deadweight and capacity table the total deadweight, cubic capacity and stowage factor of each type of cargo are entered in columns, from which the total deadweight and capacity of the shipment and its average stowage factor can be obtained. By comparing these figures with the cargo deadweight, the stowage capacity and the stowage factor of the ship, it can be seen whether she can take the whole shipment, and if so the amount which can be stowed below,

the amount which must be carried as deck cargo, and any broken stowage. Suppose, for example, a shipment with a deadweight of 5,830 tons, a capacity of 350,000 cu. ft, and an average stowage factor of 60 is required to be loaded in the ship whose particulars have just been given. At first glance it would appear that the whole shipment could be stowed below, but an allowance must be made for broken stowage; assuming this to be 10 per cent of the ship's bale capacity, the available capacity will be reduced to 325,854 cu. ft and therefore some 24,000 cu. ft must be carried as deck cargo.

The tables of heavy, fragile and filler cargoes will enable a rough plan of the stowage to be made, having regard to the requirements of stability, trim, stresses and separation; and items suitable for deck cargo, some of which may comprise dangerous goods, can be selected. Optional cargo, of which there is not usually a large amount, will probably be stowed in an upper 'tween deck, and special cargo in the locker.

The table of heavy lifts should show those items of cargo which alone weigh more than a derrick is capable of hoisting when rigged with a single whip, and special arrangements must be made for any which are beyond the capabilities of the ship's derricks. In a large port most of the heavy lifts are usually loaded by dockside and floating cranes.

The table of ports of loading and discharging will show in what order the cargo should be loaded and enable the planner to arrange the dates of delivery alongside the ship of each batch of cargo. At this stage a rough check can be made of the effect of the general distribution of the cargo on the stability and trim of the ship.

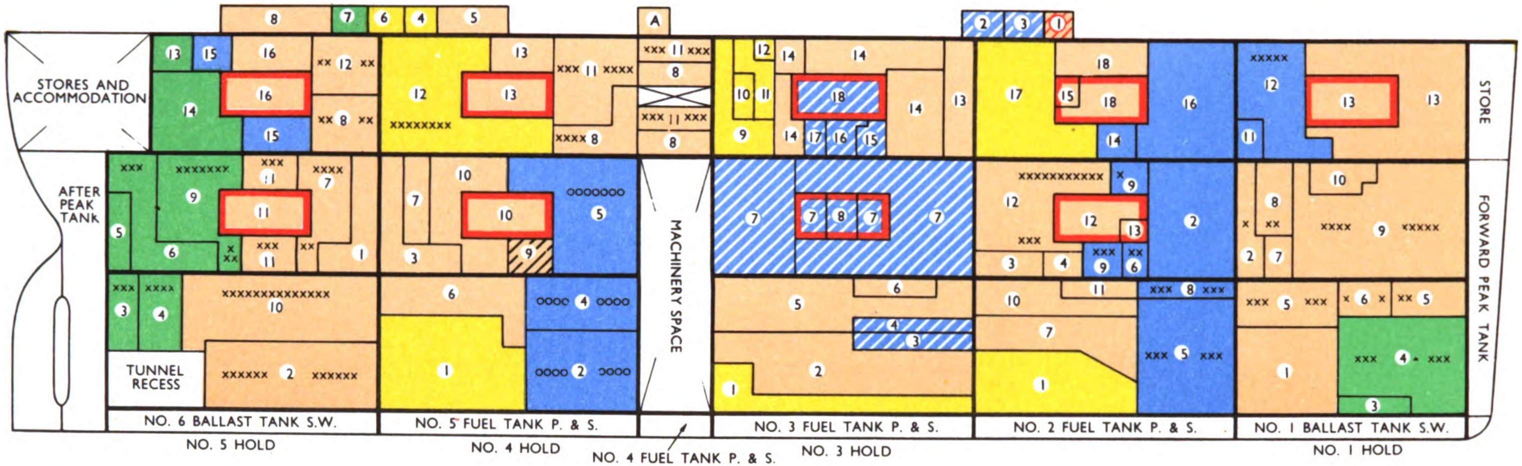
Stowage plan

The third stage is to make out a detailed plan of the stowage. Such plans show a sectional elevation of the ship in an exaggerated and much simplified form, and some also include deck plans and cross-sections of the holds. The details usually comprise the total deadweight in each hold, heavy lifts, deck cargo, special cargo, livestock (if any), the ship's particulars (such as her draughts, freeboard, dimensions, bunkers, metacentric height) and ports of loading and discharging. It is also usual to include the metacentric height for the worst possible condition of the ship during her voyage—that is, with her fuel and water nearly exhausted—giving her two slack tanks and an otherwise empty double bottom. An actual stowage plan for the s.s. *Clan Maclennan*, of the Clan Line, homeward bound from India and Ceylon to the United Kingdom and the Continent, with five ports of loading and five of discharging, is reproduced in fig. 4–3 by kind permission of the managers, Messrs. Gayzer, Irvine and Co. Ltd. She is an open, shelter-deck type of ship, and approximately 8 ft should therefore be added to the freeboards shown in the plan to give the actual freeboard up to the upper deck. A detailed study of this plan will show how the various stowage requirements just enumerated have been met.

When the plan is completed, as accurate an estimate as possible must be made of the effects of the loading and discharge of cargo on the stability and trim of the ship, and the plan must be adjusted as necessary. Copies of the plan and the cargo manifest are then sent to the stevedoring firms, to the company's agents at the various ports of call, to the head offices of the company if it has

Fig. 4–3

EXAMPLE OF A GENERAL CARGO STOWAGE PLAN



S.S. CLAN MACLENNAN—SHIP'S PARTICULARS

PORT		DRAUGHTS			FREE-BOARD	G.M.	BALLAST			
		FORD.	AFT.	MEAN			F.P.T.	NO.1	NO.6	A.P.T.
MORMAGOA	ARR.	10′ 6″	16′0″	13′3″	16′ 2½″	+5·9′	F.W. 125 TONS	S.W. 112 T.	NIL	NIL
	DEP.	14′ 1″	19′5″	16′9″	12′ 8½″	+7·0′	F.W. 125 T.	S.W. 112 T.	NIL	NIL
KOZHIKODE	ARR.	12′10″	20′4″	16′7″	12′10½″	+6·9′	NIL	NIL	NIL	NIL
	DEP.	13′ 9″	21′2″	17′5½″	12′ 0″	+5·4′	NIL	NIL	NIL	NIL
COCHIN	ARR.	13′ 9″	21′2″	17′5½″	12′ 0″	+5·4′	NIL	NIL	NIL	NIL
	DEP.	17′ 3″	23′3″	20′3″	9′ 2½″	+5·6′	F.W. 125 T.	NIL	NIL	F.W. 60 T.
ALLEPPEY	ARR.	17′ 3″	23′3″	20′3″	9′ 2½″	+5·6′	F.W. 125 T.	NIL	NIL	F.W. 60 T.
	DEP.	19′ 7″	23′5″	21′6″	7′11½″	+5·4′	F.W. 125 T.	NIL	NIL	NIL
GALLE	ARR.	19′10″	23′0″	21′5″	8′ 0½″	+5·4′	F.W. 125 T.	NIL	NIL	NIL
	DEP.	25′ 6″	26′0″	25′9″	3′ 8½″	+3·8′	F.W. 125 T.	NIL	NIL	F.W. 50 T.
SUMMER SEASONAL		26′0¾″	26′0¾″	26′0¾″	3′ 4¾″	MAX. DISPL.		13,641 T.		
BUNKERS		526	FRESH WATER: BOILERS—420 T. DOMESTIC—120 T.							

WORST CONDITION FUEL AND WATER IN D.B. NEARLY EXHAUSTED G.M.+2·7′

CARGO KEY

	PORTS OF DISCHARGE
	PORT SAID
	LONDON
	ANTWERP
	HAMBURG
	GLASGOW
	PORT SAID OPTIONAL LONDON
	LONDON OPTIONAL HAMBURG
O O O	DHOLLS FOR HAMBURG
X X X	DHOLLS FOR GLASGOW
	CARGO ON TWEEN DECK HATCH SQUARES

DISPOSITION OF CARGO DEADWEIGHT ON DEPARTURE

COMPARTMENT	MORMAGOA	KOZHIKODE	COCHIN	ALLEPPEY	GALLE	TOTALS
NO. 1 L/HOLD		94	108			202
NO. 1 L/TWEEN		20	123			143
NO. 1 U/TWEEN			4		171	175
NO. 2 L/HOLD	1,203		294	275		1,772
NO. 2 L/TWEEN		136	22	234		392
NO. 2 U/TWEEN				54	441	495
NO. 3 L/HOLD			89	17	746	852
NO. 3 L/TWEEN					583	583
NO. 3 U/TWEEN		105	63	21	174	363
NO. 4 L/HOLD	797	125	230			1,152
NO. 4 L/TWEEN		75	94	93		262
NO. 4 U/TWEEN		1	42	90	354	487
NO. 5 L/HOLD		33	107	48		188
NO. 5 L/TWEEN			86	63		149
NO. 5 U/TWEEN			38	13	111	162
ON DECK			20		20	40
TOTALS	2,000	589	1,320	908	2,600	7,417

STOWAGE PLAN — S.S. CLAN MACLENNAN FROM: INDIA AND CEYLON TO UNITED KINGDOM AND CONTINENT.
MORMAGOA, KOZHIKODE, COCHIN, ALLEPPEY & GALLE TO PORT SAID, LONDON, ANTWERP, HAMBURG & GLASGOW

(For Key to Details of Cargo see opposite page)

KEY TO STOWAGE PLAN OF S.S. "CLAN MACLENNAN"

NO. 5 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
1	PEPPER	538 BAGS	33	KOZHIKODE
2	COIR YARN (ROTTERDAM)	250 BALES	40	COCHIN
3	CASHEW KERNELS	150 CASES	5	COCHIN
4	NUX VOMICA	946 BAGS	60	COCHIN
5	PERSONAL EFFECTS	7 CASES	1	COCHIN
5	MATS & MATTING	21 PKGS.	1	COCHIN
6	NUX VOMICA	654 BAGS	42	COCHIN
7	PEPPER	680 BAGS	41	COCHIN
8	GLYCERINE (ROTTERDAM)	40 DRUMS	10	COCHIN
8	CHAULMOOGRA OIL	56 CASES	2	COCHIN
8	NUX VOMICA	400 BAGS	25	COCHIN
9	COIR YARN	10 BALES	2	ALLEPPEY
9	MATS & MATTING	510 PKGS.	29	ALLEPPEY
10	MATS & MATTING	760 PKGS.	48	ALLEPPEY
11	MATS & MATTING	605 PKGS.	32	ALLEPPEY
12	MATS & MATTING	189 PKGS.	11	ALLEPPEY
13	MATS & MATTING	10 PKGS.	1	ALLEPPEY
14	RUBBER	450 BALES	50	GALLE
15	RUBBER	460 BALES	51	GALLE
16	RUBBER	931 BALES	110	GALLE
X	COIR YARN	3,780 DHOLLS	4	COCHIN

SHIP'S OFFICE

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
A	CINNAMON BARK OIL	1 CASE	—	GALLE

NO. 4 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
1	MANGANESE ORE	IN BULK	797	MORMAGOA
2	COIR YARN	763 BALES	120	KOZHIKODE
2	PALMYRA FIBRE	13 BALES	2	KOZHIKODE
3	COIR YARN	449 BALES	73	KOZHIKODE
4	COIR YARN	407 BALES	65	COCHIN
5	COIR YARN	562 BALES	89	COCHIN
6	CASHEW KERNELS	5,636 CASES	165	COCHIN
7	CASHEW KERNELS	165 CASES	5	COCHIN
8	MATS & MATTING	552 PKGS.	30	COCHIN
8	PERSONAL EFFECTS	5 CASES	1	KOZHIKODE
9	COIR YARN	50 BALES	9	ALLEPPEY
10	COIR YARN	4 BALES	1	ALLEPPEY
10	MATS & MATTING	1,388 PKGS.	83	ALLEPPEY
11	MATS & MATTING	1,561 PKGS.	90	ALLEPPEY
12	POONAC	4,482 BAGS	224	GALLE
13	RUBBER	1,119 BALES	130	GALLE
O	COIR YARN	1,980 DHOLLS	5	KOZHIKODE
X	COIR YARN	5,800 DHOLLS	12	COCHIN

NO. 3 HOLD (contd.)

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
16	PEPPER (MARSEILLES)	64 BAGS	4	COCHIN
17	COIR YARN (GENOA)	50 BALES	9	ALLEPPEY
18	RUBBER	478 BALES	54	GALLE
—	COCONUT HUSKS	—	98	GALLE
X	COIR YARN	200 DHOLLS	1	COCHIN

NO. 3 HOLD

PLAN NO.	COMMODITY	QUANTITY	W.T TONS	LOADING PORT
1	COCONUT OIL	301 DRUMS	155	GALLE
2	COCONUT OIL	829 DRUMS	420	GALLE
3	COCONUT OIL	107 DRUMS	60	GALLE
4	COIR YARN	160 BALES	25	COCHIN
5	MATS & MATTING	1,142 PKGS.	64	COCHIN
5	MATS & MATTING	218 PKGS.	17	ALLEPPEY
6	COIR NET BAGS	44 BALES	5	GALLE
6	COIR YARN	75 COILS	8	GALLE
7	COCONUT OIL	1,069 DRUMS	550	GALLE
8	RUBBER	287 BALES	33	GALLE
9	COIR YARN	302 BALES	48	KOZHIKODE
10	COTTON YARN	112 BALES	20	COCHIN
10	COIR YARN	25 BALES	4	COCHIN
10	PEPPER	16 BAGS	1	COCHIN
11	COIR YARN	70 BALES	13	ALLEPPEY
11	MATS & MATTING	57 PKGS.	1	ALLEPPEY
12	RUBBER	135 BALES	15	GALLE
13	COTTON YARN (MONTEVIDEO)	50 CASES	6	COCHIN
14	COIR YARN	343 BALES	62	GALLE
14	RUBBER	268 BALES	35	GALLE
14	CINNAMON	25 BALES	1	GALLE
14	COIR YARN	75 COILS	7	GALLE
15	COIR YARN (MARSEILLES)	306 BALES	49	KOZHIKODE
15	COIR YARN (TRIPOLI)	25 BALES	3	KOZHIKODE
15	PEPPER (GENOA)	80 BAGS	5	KOZHIKODE
16	COIR YARN	170 BALES	27	COCHIN

NO. 2 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
1	MANGANESE ORE	IN BULK	1,203	MORMAGOA
2	COIR YARN	545 BALES	89	KOZHIKODE
2	PEPPER	59 BAGS	4	KOZHIKODE
3	COIR YARN	75 BALES	13	KOZHIKODE
3	PALMYRA FIBRE	67 BALES	10	KOZHIKODE
4	ROSEWOOD (LE HAVRE)	19 LOGS	20	KOZHIKODE
5	COIR YARN	1,356 BALES	217	COCHIN
6	PEPPER	251 BAGS	16	COCHIN
7	COIR YARN	464 BALES	74	COCHIN
8	COIR YARN	271 BALES	43	ALLEPPEY
9	COIR YARN	630 BALES	100	ALLEPPEY
10	COIR YARN	1,259 BALES	220	ALLEPPEY
11	MATS & MATTING	544 PKGS.	12	ALLEPPEY
12	MATS & MATTING	2,200 PKGS	122	ALLEPPEY
13	CASHEW KERNELS	275 CASES	12	ALLEPPEY
14	COIR YARN	329 BALES	53	ALLEPPEY
15	MATS & MATTING	31 PKGS.	1	ALLEPPEY
16	COIR YARN	652 BALES	130	GALLE
17	POONAC	3,018 BAGS	151	GALLE
18	RUBBER	1,387 BALES	160	GALLE
X	COIR YARN	5,480 DHOLLS	9	COCHIN

NO. 1 HOLD

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
1	TEA	1,796 CHESTS	92	KOZHIKODE
2	TEA	414 CHESTS	20	KOZHIKODE
3	COIR YARN	13 BALES	2	KOZHIKODE
4	COIR YARN	275 BALES	44	COCHIN
5	TEA	1,035 CHESTS	56	COCHIN
6	MATS & MATTING	85 PKGS.	5	COCHIN
7	TEA	135 CHESTS	6	COCHIN
8	TEA	183 CHESTS	12	COCHIN
9	COIR YARN	610 BALES	95	COCHIN
10	MATS & MATTING	123 PKGS.	7	COCHIN
11	TEA	71 CHESTS	3	COCHIN
12	COIR YARN	343 BALES	68	GALLE
13	COIR YARN	479 BALES	93	GALLE
13	COIR NET BAGS	101 BALES	10	GALLE
X	COIR YARN	4,000 DHOLLS	7	COCHIN

ON DECK

PLAN NO.	COMMODITY	QUANTITY	WT. TONS	LOADING PORT
1	LEMON GRASS OIL	8 DRUMS	2	COCHIN
2	LEMON GRASS OIL	18 DRUMS	5	COCHIN
3	CITRONELLA OIL	19 DRUMS	3	GALLE
4	LEMON GRASS OIL	4 DRUMS	1	COCHIN
5	LEMON GRASS OIL	63 DRUMS	12	COCHIN
6	CITRONELLA OIL	14 DRUMS	2	GALLE
7	CITRONELLA OIL	6 DRUMS	1	GALLE
8	CITRONELLA OIL	84 DRUMS	14	GALLE

been made out in the ship or abroad, and to the Master of the ship if it has been made out in the company's offices.

The initial plan, usually called a *pro forma*, may be subject to considerable revision after it is first made out. The stevedoring firms may require minor alterations to suit the handling of particular types of cargo or to comply with certain conditions of labour; some cargo may be delayed in transit, some cancelled, and some added; and finally the Master, who is ultimately responsible for both his ship and her cargo and who therefore has the last say in the matter, may require some adjustments to suit any peculiarities or features of his ship.

Loading organisation

The fourth and final stage in planning is to estimate the time required to load the cargo, fix the provisional date of sailing, arrange the fuelling, storing and watering of the ship and her arrival at her loading berth, and to arrange the delivery of the cargo to fit in with the loading schedule.

Port speed at one port may vary considerably from that at another, because it depends largely on the skill of the stevedores, the hours of work and other conditions of labour, and in the same port one gang of stevedores may work much better than another. Knowledge of local capabilities and conditions is therefore of great value when estimating the time required for loading or discharging a cargo. Port speed will also depend upon the type of cargo being handled; cargo made up of small, light packages usually takes longer to load or discharge than heavy cargo or large items such as trucks. For a general cargo, however, an average rate of 10 tons per hour per gang, working an eight-hour day on general cargo, can be taken as a basic guide.

Taking the port speed as the basis of computation, and assuming that the loading schedule has been arranged to employ all hatches simultaneously, the following example shows how a rough estimate can be made of the time required to load the ship.

EXAMPLE

A total of 1,560 tons deadweight of cargo is to be loaded into a ship with four holds, and distributed as follows: No. 1 hold—400 tons, No. 2 hold—480 tons, No. 3 hold—320 tons, and No. 4 hold—360 tons. Four gangs are employed, one to each hold and each working an eight-hour shift. Assuming the port speed is 10 tons per hour per gang, how long will it take to load the ship?

First find the total hours and the number of days required for each hold, thus:

	Cargo deadweight	*Total hours at 10 t.p.h.*	*Days at 8 hours per day*
No. 1	400	40	5
No. 2	480	48	6
No. 3	320	32	4
No. 4	360	36	4½

It will be seen that sailing is being delayed by Nos. 1 and 2 holds and, if port facilities allow, it might be advantageous to employ an extra shift of four hours on No. 1 hold and extra shifts of 8 hours and 4 hours on No. 2 hold, thus reducing the loading time to 4½ days for all holds.

The loading rate of 10 tons an hour is a fair average, and in practice it will be found that the actual rate will be faster than the port speed at the beginning of the operation and then become progressively slower as the holds fill up, until at the end it will be much slower than the port speed. This is because it is easier to work in an empty or partially-filled hold than in a nearly full one, and the lower tiers of cargo are usually of a heavy or robust nature which can be loaded at a greater rate than fragile or filler cargoes.

An allowance must also be made for the weather: some cargoes cannot be loaded or discharged in wet weather, and some dangerous goods must not be handled during a thunderstorm.

The loading schedule must be carefully planned to ensure that the cargo is delivered alongside, either on the quay or in lighters, at the time ordered for its loading so as to avoid any delays or congestion. A special schedule should be made out for heavy lifts, particularly those which have to be handled by cranes.

HANDLING A GENERAL CARGO

It is not intended here to give a detailed description of the various methods of handling, slinging and hoisting cargo, because the experienced seaman has a good knowledge of the principles involved, and their application is a matter of common sense. Some notes are given, however, on the duties of a gang of stevedores and the measurement, marking and methods of stowing general cargo.

Composition of a gang

The composition of a gang of stevedores varies at different ports and with different types of cargo and ship, but the average gang employed in British ports at each hold of an ocean-going cargo liner comprises the following:

Gang foreman. He is in general charge of the gang, and should have a thorough knowledge of stevedoring. His station is on deck beside the upper hatch when discharging cargo, and in the hold when loading.

Hatchwayman. When loading cargo his station is on deck beside the upper hatch, and he is responsible for seeing that the cargo is lowered safely into the hold. When discharging cargo his place is taken by the gang foreman.

Winchmen. These work the derrick winches under the orders of the gang foreman or the hatchwayman. There are one or two to each gang, depending on the derrick rig in use.

Stevedores. Eight stevedores usually work in the hold and six on the quayside or in the lighter.

In addition, there are a tally clerk, who tallies each item of cargo as it is loaded or discharged, and a checker who measures the cubic capacity of separate items or batches of cargo; they are usually provided by the shipowner or the stevedoring firm. There are also the men who place or remove the cargo at the loading or discharging dumps.

Measurement of cargo

Cargo is measured for two reasons—to decide whether its freight charges will be levied on a basis of deadweight or of cubic capacity, and secondly to ascertain the approximate space it will occupy when stowed. Freightage on cargo which

stows at less than 40 cu. ft to the ton is usually charged by deadweight, and other cargo by cubic capacity. The cubic capacity of an irregularly-shaped item of cargo is measured as if it were exactly contained in a box of regular shape, and its measurement is therefore the product of its maximum length, breadth and height. The measurement of a cylindrical or circular object, such as a drum or tyre, would be the product of its length or breadth and the square of its diameter. Most items of cargo are marked by the manufacturer or consignee with their net weight and dimensions, but these are usually checked at the wharf before loading.

Marking of cargo

Most items of cargo are marked by the manufacturer or consignor to indicate their origin, destination and sometimes their nature. Some dangerous cargoes must by law be painted red or pink or labelled 'Dangerous'. This system of marking, however, is used only to identify specific items of cargo before they are loaded or after they are discharged, and is of little use to distinguish one batch of cargo from another when stowed in a hold.

The clear designation of cargo destined for different ports, and sometimes of batches destined for the same port, is essential for its quick discharge and to avoid over-carriage and short-landing. Ships' officers usually devise their own code for this purpose, consisting of colours and designs to distinguish the different consignments. A code in general use is to allot a colour for each port of discharge and a shape such as a square, a circle, a diamond or a cross for particular batches. These designs are sometimes stencilled on each item (or on the boundary items of each parcel) as it is stowed. Other means of distinguishing one cargo from another are by tarpaulins, matting, old rope, and water paints.

METHODS OF CARGO STOWAGE

The correct method of stowing a cargo and the efficient and economical use of dunnage is largely a matter of experience and common sense, and the following remarks are intended only as a general guide.

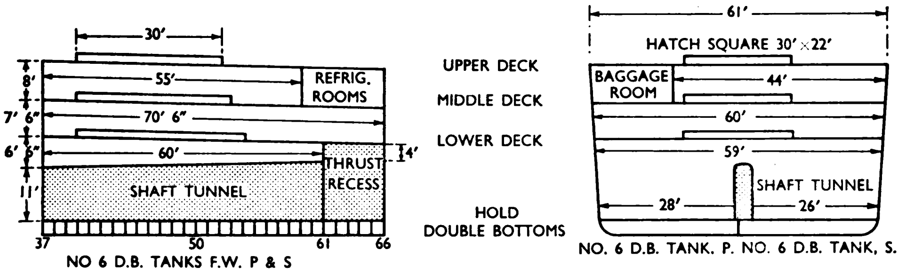
Hold plans

A plan of each hold is usually included in a ship's plans, but the details given are only of a very general nature and seldom include exact measurements of the actual deck areas or bale capacities available. Most ships' officers therefore make out their own plans on the lines shown in fig. 4–4, to show the deck areas available, any obstructions such as pillars and shaft tunnels, and the actual bale capacity of each hold, taking into account the shape of the hold and all obstructions to stowage within it. Such plans may subsequently be corrected as the result of experience gained in stowing various types of cargo.

Bottom and side dunnage

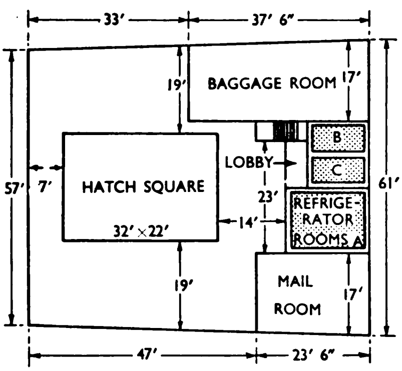
If bottom dunnage has to be laid beneath a batch of cargo—as when a hold is not fitted with a permanent ceiling, or when extra ventilation space is required beneath a cargo—the planking should be laid forward and aft over athwartship bearers to allow any moisture from the cargo or sweat from the bulkheads to

NO. 4 HOLD—CARGO PLANS

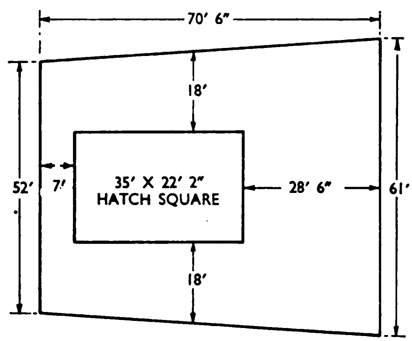


Sectional elevation through centre-line

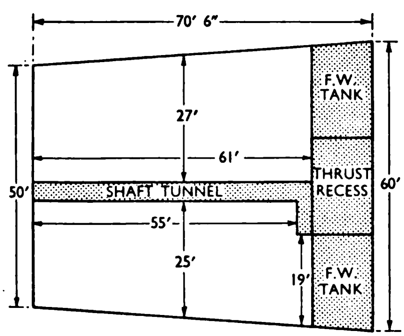
Cross section at No. 50 Frame



Plan of upper 'tween deck



Plan of lower 'tween deck



Plan of hold

COMPARTMENT	FRAMES	GRAIN Cu.ft	BALE Cu.ft
LOWER HOLD	38-61	41,800	
LOWER 'TWEEN DECK	38-66	33,970	
UPPER 'TWEEN DECK	38-59	24,020	
HOLD TOTAL		99,790	88,270
MAIL ROOM	56-66,S.		3,100
BAGGAGE ROOM	50-66,P.		4,890
TOTAL BAGGAGE AND MAIL			7,990
REFRIGERATOR ROOM, STARB.	56-66		1,090
REFRIGERATOR ROOM, CENTRE	61-66		540
REFRIGERATOR ROOM, PORT	61-66		300
TOTAL REFRIGERATOR CARGO			1,930

FIG. 4–4. Example of the plans of a cargo hold

run across to the limber holes in the wings and so down to the bilges. When no cargo battens or sparring are fitted, planking should be lashed horizontally across the hold frames or held in place by upright quartering secured by wedges.

Methods of stowing

The general rule in stowing is to start in the wings and ends of a holc work towards its centre, and when discharging to work from the centre outw: Another general rule is to stow evenly and maintain as level a surface as possible as stowage progresses, but this may not be possible when stowing large items of irregular shape, or when cargo for different destinations has to be stacked in separated blocks.

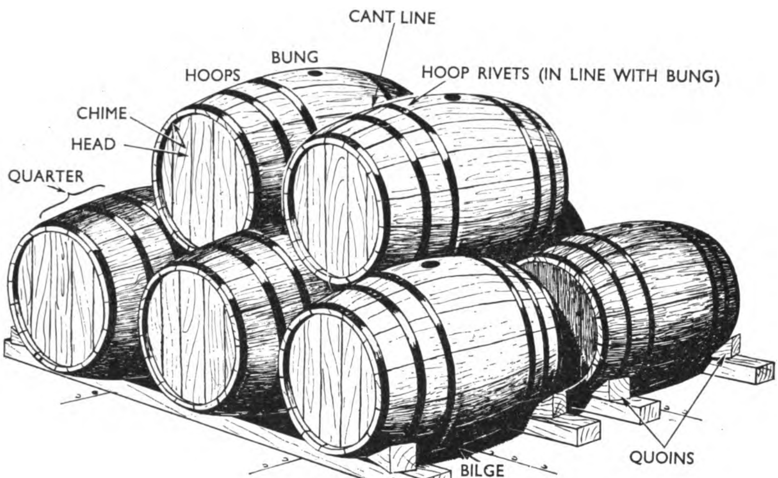


FIG. 4–5. Casks stowed 'bilge and cantline', with bung uppermost and bilge free

Regularly-shaped cargo of one type, such as that contained in cases, bales and bags, is stowed in tiers, and dunnage may be necessary between tiers to distribute the weight of the upper tiers evenly over the lower tiers. When cargo for different destinations is stowed together it is either stacked in blocks separated from each other by horizontal planking kept in place by upright quartering, or by stepping down the cargo so that the removal of one cargo will not necessitate the restowage of the remainder.

Drums are stowed side by side vertically in tiers with their bungs uppermost, and casks should be stowed 'bilge and cantline' with their bungs uppermost, as shown in fig. 4–5. Dunnage should be laid between tiers of drums, and the table below shows the maximum number of tiers for different types of casks.

MAXIMUM NUMBER OF TIERS FOR CASKS

Type of Cask	Capacity in Gallons		Maximum Number of Tiers
	British	Wine	
Butts or Pipes	105	126	3–4
Puncheons	60–100	72–120	4
Hogsheads	52½	63	6
Tierces	35	42	7

Heavy lifts should, when possible, be stowed lengthwise fore-and-aft on diagonally-placed bearers to ensure an even distribution of weight over the floors of the hold. If they have to be stowed athwartships, the bearers must be laid over the floors of the hold and never between them.

When bulk cargo is stowed with general cargo the former is usually overstowed by the latter, but it is important to ensure that the two types are well separated by matting, cloths, tarpaulins or other dunnage.

CHAPTER 5

Safety Arrangements in Merchant Ships

Men-of-war are often called upon to go to the assistance of merchant ships in distress after collision or grounding or when on fire. Such tasks as rescue of passengers and crew, putting out fires, taking in tow and salvage of merchant ships, or the placing of a crew on board an abandoned merchant vessel may arise at any time without warning. H.M. ships must therefore be prepared for this sort of work. Some knowledge of the construction of merchant ships and of their firefighting and lifesaving arrangements is essential to the naval officer. The great variety of merchant shipping precludes a detailed description of these features, but it is hoped that this chapter will provide a general idea of them, and will show the principal ways in which they differ from those of warships. Lifesaving arrangements in H.M. ships are described in Volume II, in the chapter on abandoning ship, survival and rescue.

International Conference on Safety of Life at Sea

The principal maritime nations of the world subscribe to the regulations agreed and published by the International Conference on Safety of Life at Sea, which meets from time to time. These regulations include not only those governing prevention of collisions at sea (commonly called the *Rule of the Road*), but also give detailed rules on construction so as to provide adequate watertight subdivision and stability in certain types of ship, and the safe installation and functioning of certain types of machinery. The rules lay down standards for fire precautions and firefighting equipment and for the provision of lifesaving appliances. They also deal with safeguards concerning navigation, the carriage of dangerous goods, nuclear-powered ships and other matters. The full rules are published by Her Majesty's Stationery Office, the latest being given in the report of the International Conference on Safety of Life at Sea held in London in 1960. At the time of going to press the rules agreed at this conference have not yet been ratified by the various nations, but it is probable that they will be, and for this reason the information given in this chapter is based mainly on the results of the 1960 conference.

In addition, the construction and seaworthiness of merchant shipping generally are subject to the demands of the Classification Societies, such as Lloyd's Register. In the U.K. there are also various statutory requirements concerning safety laid down under the provisions of the *Merchant Shipping Acts.*

WATERTIGHT SUBDIVISION

Standards for merchant ships generally

In addition to increasing the safety of a ship by limiting the inflow of water resulting from bad weather or damage, watertight subdivision provides cellular stowage for fuel, water and stores, and also a means of correcting any trim or

list and of increasing the stability of the ship by pumping or counter-flooding. Too much subdivision, however, limits the space for cargo, hinders communication between different parts of the ship, complicates the arrangements for draining, pumping and ventilating, and increases the number of men required to work the ship. For these reasons it is clear that subdivision cannot be carried to the same degree in a merchant ship as in a man-of-war.

No definite rules regarding subdivision were laid down for British passenger ships until 1914, when rules were formulated after the sinking of the White Star liner *Titanic* in mid-Atlantic in 1912 with great loss of life after she had collided with an iceberg. Various 'Bulkhead Committees' have met since then, and the present rules are based on those formulated by the International Conference on Safety of Life at Sea, at their meeting in London in 1960.

Certain minimum standards of watertight subdivision are made compulsory by law for passenger-carrying merchant ships, but these regulations apply only to ships carrying more than 12 passengers. The only rules governing the watertight subdivision of cargo ships are those of the Classification Societies (see Chapter 3) which specify the minimum number of bulkheads according to the length of the ship; Lloyd's Register, for example, requires four bulkheads in ships under 285 ft in length, and lays down a scale rising to nine bulkheads for vessels between 540 and 610 ft in length. The spacing between bulkheads is not specified, but must be reasonable.

Regulations for passenger ships

The regulations for passenger ships formulated in 1960 by the International Conference provide for:

1. a minimum standard of watertight subdivision for various types of ships;
2. the arrangement of such subdivision to ensure that the ship will remain afloat when one or, in certain cases, two or three major compartments are flooded;
3. a sufficient margin of stability for the safe operation of the ship;
4. precautions to prevent the spread of fire.

The standard of subdivision varies with the type of ship, and the highest degree is required in ships of the greatest length and engaged primarily in carrying passengers.

The following terms are used when fixing the maximum permissible spacing of the bulkheads in any particular passenger ship:

the *bulkhead deck* is the uppermost deck to which the transverse watertight bulkheads are carried;

the *margin line* is a line parallel to, and three inches below, the bulkhead deck where it meets the ship's side;

the *floodable length* at any position in a ship is the length of the longest possible watertight compartment, having its centre at the selected point, the flooding of which would not quite submerge the margin line;

the *permissible length* is the maximum permissible distance between watertight bulkheads. This distance is usually less than the floodable length (though never more) and is related to it by the *factor of subdivision*. This factor takes into account the length of the ship and the degree to which she is

designed for the carriage of passengers, the value being less as length increases and as passenger-carrying tends to predominate over cargo-carrying. The smaller the factor, the higher is the standard of subdivision; for example, if the factor is *one-half* or less, the flooding of any *two* adjacent compartments will not submerge the ship to her margin line; and, similarly, if the factor is *one-third* or less, the ship will survive the flooding of any *three* adjacent compartments.

To ensure that draught does not exceed that used in determining the degree of subdivision, a passenger ship is marked with a subdivision load line (commonly called a *convention line*) alongside her other load lines, and when she is carrying more than 12 passengers she must not be loaded to an extent that will submerge this mark. Ships in which extra accommodation may occasionally be provided for passengers, e.g. ships chartered for the pilgrim trade or as troopships, are marked with two, and sometimes three, of these lines to conform with the number of her passengers and the situation of their accommodation. The lines may, for example, be marked C_1, C_2 or C_3 accordingly, and in British ships their positions are assigned by the Ministry of Transport's surveyors.

Very close subdivision is not necessarily an advantage because, if too close, a watertight compartment may be so short that damage may cause flooding both before and abaft it. For this reason the regulations specify a minimum spacing between bulkheads.

Longitudinal bulkheads may limit the amount of flooding and help to preserve the waterplane area, but they may also cause the ship to heel badly by confining the flood water to one side of the ship. It is therefore specified that the angle of heel which would be caused by flooding any wing compartment as a result of damage shall neither exceed 7°, nor submerge the margin line under normal circumstances, after any prescribed measures to restore stability have been taken.

Apart from the spacing of transverse and longitudinal watertight bulkheads, the effects of watertight decks, inner skins and similar structures on heel and stability are also required by regulations to be carefully examined.

A typical watertight door in a passenger ship slides across to close, and is a machined fit, metal to metal. There is neither rubber nor clips such as are found on a Service door. Such doors can be closed locally by hand, or by remote control from the bridge. When the doors are closed by remote control, a gong sounds by the door to warn people in the vicinity to keep clear. After being closed from the bridge, the door can still be opened locally by hand, but will close again automatically after a fixed delay of, say, 5 seconds.

A typical bridge control panel will display drawings of the ship with indicator lights in the various watertight door positions. Each door can be closed by a switch, and the appropriate indicator light will glow when the door is closed.

Bulkheads constructed for preventing fire from spreading are required to be fitted above the bulkhead deck, to subdivide the structure into vertical zones. They must be of steel or of material of comparable fire-resistant quality and of adequate scantlings and stiffening, and they must be fire-resistant. The mean distance between any two such bulkheads normally must not exceed 131 ft, and the means of closing all openings in them must be fire-resisting and flametight. Further subdivision of these main spaces is required unless automatic fire-alarm and extinguishing systems are fitted. Where spaces require special protection

(for example, control stations or stairways forming vertical escape routes), or where there is a special fire risk (for example, in main machinery spaces and galleys), such spaces must be enclosed by fire-resistant bulkheads.

FIRE PRECAUTIONS

The minimum standard of firefighting equipment to be carried in merchant ships is laid down in the *Merchant Shipping Acts*, and the number and types of appliances to be carried vary according to:

1. the size of the ship;
2. whether she carries passengers or cargo, or both;
3. the type of cargo carried;
4. whether she has oil-fired boilers, is coal-burning, or is motor-driven.

A general description of the firefighting equipment in a large ocean-going merchant ship is given in the following paragraphs, with notes, where appropriate, on the equipment fitted in tankers.

FIG. 5–1. Typical anti-fire door in a passenger liner. The door slides to close, and is fire-resisting and flametight

Fixed systems

Fire doors. As already mentioned, the openings in all bulkheads designed to prevent fire from spreading must be fire-resisting and flametight. A typical anti-fire door is shown in fig. 5–1.

Firemain. This system, known in the Merchant Navy as the *wash-deck service*, supplies hydrants suitably disposed about the ship. Water is delivered to the system by pumps, which in the older ships are all in the engine room, but in

modern ships are dispersed among several compartments. Each fire pump in the system is capable of providing two powerful jets of water at any section of each deck limited by the watertight and fire-resisting doors. The 2½-in. instantaneous coupling is usually provided for all the fire hydrants. Hoses and branchpipes are not usually kept coupled to the hydrants, as in H.M. ships, but are enclosed in glass-fronted cases fitted in prominent positions. Passenger and cargo ships of 1000 tons gross and upwards must have at least one international-type shore connection for the firemain, and must also have an emergency fire pump.

The basic firefighting installation in the majority of tankers also consists of a fixed water main extending the whole length of the vessel, with branches to the machinery, accommodation and storage spaces.

Sprinkler systems. Automatic sprinkler systems are often provided in passenger and crew spaces. These are usually supplied with fresh water from a sprinkler tank under pneumatic pressure, supplemented by pumps which automatically come into operation immediately the water pressure in the system begins to drop. It is common practice for each sprinkler to incorporate a soluble plug, which melts when the temperature round it reaches a certain degree, thus bringing the sprinkler into operation automatically.

On a passenger liner there is often a control panel on the bridge showing by means of indicator lights where any sprinkler in the ship has started to operate.

Smothering-gas, steam and foam-making systems. In cargo ships all cargo spaces (unless specifically exempted) are fitted with a system which injects smothering-gas or steam into each space in an emergency. The smothering-gas, usually carbon dioxide, is contained in cylinders fitted in the superstructures forward and aft, and panels are fitted on which are mounted the operating valves and a diagram indicating the various spaces served by the system.

Boiler rooms (and the motor rooms of motor ships) are fitted with either a pressure water spraying system, or a smothering-gas installation, or a fixed foam installation.

The steam smothering system installed in the majority of tankers and cargo vessels consists of a main steam line running the length of the ship, with small branch pipes to each tank or cargo hold. Shut-off valves control the flow to individual tanks, and the whole system is controlled by a master valve located in or near the engine room. Normally in a tanker the individual tank valves are kept open so that in an accident it is only necessary to open the main valve in order to flood all the tanks with steam.

The modern trend adopted in some tankers is to replace the steam smothering system with a large-capacity foam-producing system. These vessels have two fixed mains, one supplying water only and the other a 3 per cent foam-compound/water mixture. The mains are located on the main deck, one each side of the fore-and-aft bridge, and are fitted with isolating valves and crossovers to enable damaged sections of the system to be isolated. They are supplied with foam and water from storage tanks and fire pumps located at each end of the vessel. The forward fire pump is actuated by a diesel engine and is therefore independent of the engine-room power supply.

The latest method being fitted in a number of tankers is the inert-gas system. The main line layout is similar to that of the steam smothering system. The inert gas is forced into the top of each tank under pressure by blowers.

Emergency source of electrical supply. Passenger ships and cargo ships of 5000 tons gross and upwards are fitted with an emergency source of electrical power, located outside the machinery casings. This usually takes the form of a diesel generator.

Fire detection and alarm systems. These systems (often operated by the presence of smoke) are usually fitted in cargo holds and other spaces which are not easily accessible. Pipes are led from the compartments concerned to a special cabinet situated in the chartroom, or some other central place, in which a mechanical apparatus indicates when smoke is present in any compartment. At the same time an audible alarm is also operated.

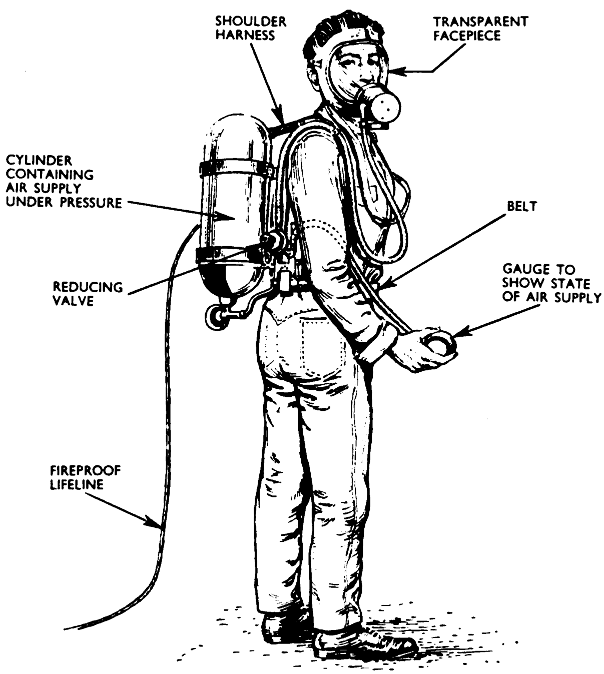


FIG. 5–2. Typical breathing apparatus used for firefighting in a merchant ship

Portable equipment

Hand extinguishers. These may be of the foam or carbon tetrachloride type, or of the type which discharges water. The latter is the one usually provided; it is of the soda-acid variety and is usually placed near the entrance to each space occupied by passengers, officers or crew. Portable foam extinguishers are placed in compartments containing internal combustion machinery, and also in boiler rooms.

Breathing apparatus. Suitable types of breathing apparatus are provided, to permit entry into smoke-filled spaces. One type of breathing apparatus commonly in use is illustrated in fig. 5–2.

Electric drilling machines. In ships other than tankers, where electric power is

available, electric drilling machines are provided as an emergency means of obtaining access to fires through bulkheads, decks or casings. Oxy-acetylene cutting gear is seldom provided.

Safety lamps. These are also provided, and have a minimum burning period of three hours. They must be of an electric-battery type.

Sand. In ships using oil as fuel, bins of sand are provided in the boiler rooms and machinery spaces for soaking up spills of oil.

Emergency arrangements in tankers

Pumps. Means are always provided in a tanker to connect all suitable engine-room pumps to the fire main. The large-capacity pump which supplies water to the tank-washing machines is particularly suitable for this purpose.

Many tankers are also capable of connecting one or more of the transfer pumps located in the forward pump room to the fire main in emergency, but in this case the pumps usually rely on a supply of steam from the boiler room.

Two alternative power supplies for the fire pumps must be provided. This is usually arranged by installing an emergency diesel generator to supply power to electrically-driven pumps, or by installing a completely independent diesel-driven fire pump in the forward part of the ship.

Emergency controls. The regulations also call for means of shutting off the fuel supply to the main engines or boilers, and for stopping forced ventilation fans from a position outside the machinery spaces. In the majority of tankers these emergency controls are installed within the after accommodation, adjacent to the engine room. For obvious reasons, the controls of the carbon-dioxide smothering systems are never installed within the compartment they serve, but are located at some convenient position on the upper deck. The controls for the pump-room system can often be found on the bulkhead outside the pump-room door.

LIFESAVING APPLIANCES AND THEIR USE

The International Conference on Safety of Life at Sea (1960) permitted and approved for the first time the use of inflatable lifesaving equipment. The general description of lifesaving appliances in the Merchant Navy given here follows the provisions agreed at that conference. In the United Kingdom the Ministry of Transport issues detailed instructions, in amplification of the International Rules, controlling the specifications of all gear and laying down scales to be used in various types of merchant ship. The Ministry also appoints surveyors to inspect ships at regular intervals to ensure that their equipment is correct and is maintained at the required standard.

Classification

The six main categories of lifesaving appliances are:

1. *Lifejackets*. These are worn by individuals to support themselves in the water.
2. *Lifebuoys*. If a man falls overboard a lifebuoy is thrown for him to cling to until he can be rescued. Some lifebuoys are fitted with self-igniting lights.

3. *Buoyant apparatus.* This is a rigid structure strong enough to be thrown into the water from the place where it is stowed without suffering damage, or to float clear of a ship when it founders.
4. *Rigid liferafts.* These are similar to inflatable liferafts, except that they do not depend upon inflation for their buoyancy.
5. *Inflatable liferafts.* These are rafts that can be inflated either at their stowage position or in the water.
6. *Lifeboats.* These are specially constructed for this purpose; they may be propelled by oars, sails, mechanical means or by power, and each is rated to carry a specified number of persons.

Availability of lifesaving appliances

The general principle governing the lifeboats, liferafts and buoyant equipment carried in a ship is that they must be readily available in an emergency, and hence they must comply with the following provisions:

1. It must be possible to put the entire approved complement of lifesaving appliances of a ship into the water safely and rapidly even under unfavourable conditions of trim and of 15° of list, in not more than 30 minutes.
2. It must be possible to load the lifeboats and liferafts with their full complement of people rapidly and in good order and to get them fully loaded into the water under the conditions given above.
3. The arrangements for stowage and lowering of each lifeboat, liferaft or article of buoyant apparatus must be such that they will not interfere with the operation of other lifeboats, liferafts and buoyant apparatus.

All the lifesaving appliances on board ship must be kept in working order and made available for immediate use before the ship leaves port, and at all times during the voyage.

Lifejackets

Every ship must carry a lifejacket for every person on board, and it must be of an approved type. Unless the lifejackets can be adapted for use by children, a ship must carry a sufficient number which are suitable. A passenger ship must also carry, in addition to one lifejacket for every person on board, 5 per cent extra, and these must be stowed on deck and in a conspicuous place.

Much research into the design and capabilities of lifejackets has been carried out, particularly by the Royal Navy, since the Second World War. The results are seen in the R.N. inflatable lifejacket (described in Volume II), which complies fully with all the requirements of an ideal lifejacket. These requirements may be summarised as follows:

1. It should keep the survivor afloat with his face and nose clear of the water.
2. If the survivor is unconscious, the lifejacket should turn him, within a few seconds, on to his back to a safe floating position. In this position the body is inclined backwards at about 45°, but with the back of the head supported in such a way that the face is clear of the water.
3. The lifejacket should be easy to put on, it must be reasonably comfortable and should not interfere too much with activity.
4. It should be conspicuous in the water.

The 1960 Convention allows for the first time for the provision of inflatable lifejackets which can comply with the requirements stated. However, there are at present in use in merchant ships, yachts, etc. many lifejackets which do not measure up to these requirements.

Fig. 5–3 illustrates one type of lifejacket in use generally at the present time (1963) in the Merchant Navy. To be approved by the Ministry of Transport a lifejacket must fit around the body, be reversible so that it can be put on back

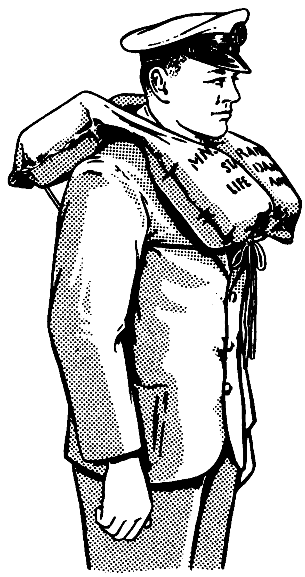


FIG. 5–3. Ministry of Transport standard non-inflatable lifejacket

to front or inside out, and be suitable for both adults and children. It must be capable of floating in fresh water for at least 24 hours with 16½ lb of iron suspended from it. Most lifejackets are made of stout linen, cotton or man-made fabric sewn with pockets into which are placed slabs of solid cork or which are stuffed with a kapok-type fibre.

Under the provisions of the 1960 Convention a lifejacket, the buoyancy of which depends upon inflation, may be supplied for use by the crews of all ships, except passenger ships and tankers, provided that it has two separate air compartments, together capable of supporting in fresh water for 24 hours 33 lb of iron, and each compartment separately capable of supporting 16½ lb of iron; that it is capable of being inflated both mechanically and by mouth; and that it conforms generally to the requirements of the non-inflatable lifejacket described above even when only one air compartment is inflated.

When putting on a lifejacket it should be very firmly secured round the body by its tapes or lines. It is not advisable to jump into the water from heights above 10 ft when wearing a lifejacket of the non-inflatable type, because on impact with the water the jacket may be forced violently upwards against the

wearer's head and so knock him out or even break his neck. If jumping into the water is unavoidable the jacket should not be put on until in the water; or if this is impracticable, the arms should be crossed on the chest with the hands on the shoulders, thus holding down the jacket on impact with the water.

Lifebuoys

In the British Merchant Navy a lifebuoy is of circular shape and is usually made of solid cork or balsa wood, and covered with painted canvas. It must not

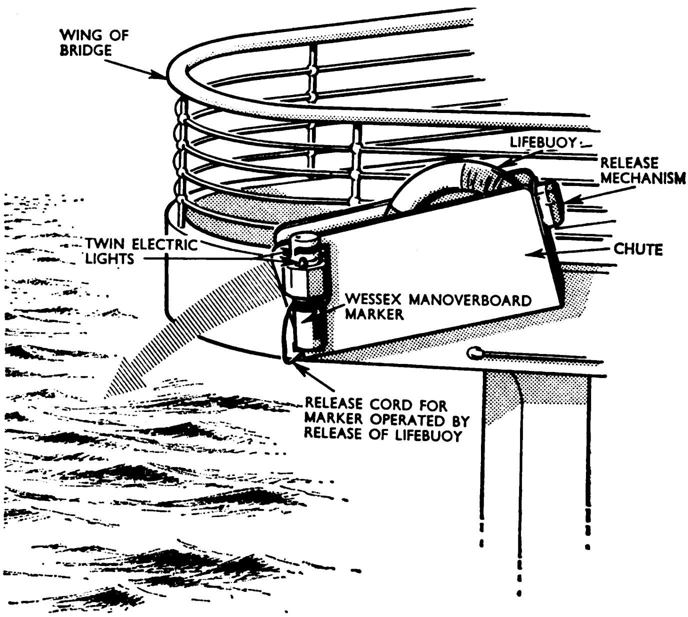


FIG. 5–4. Lifebuoy and Manoverboard marker

be filled with rushes, cork shavings, granulated cork or other substances of similar nature, and the buoyancy must not depend on air compartments or inflatable tubes. A lifebuoy should not weigh more than 13½ lb when new, should be capable of floating in fresh water for at least 24 hours with 32 lb of iron suspended from it, and should be of a highly visible colour.

Lifebuoys are placed in conspicuous and handy positions on the upper decks of a ship, and the numbers carried will depend on whether she is a cargo or a passenger ship. A cargo vessel, whether foreign-going or coastal, over 100 ft in length, must carry eight lifebuoys. A foreign-going passenger ship must carry lifebuoys in accordance with the following scale:

Length of Ship	*Minimum Number of Lifebuoys*
Under 200 ft	8
Not under 200 ft, but under 400 ft	12
Not under 400 ft, but under 600 ft	18
Not under 600 ft, but under 800 ft	24
800 ft and over	30

Similar scales are laid down for excursion and cross-Channel steamers, coastal passenger vessels, pleasure launches and similar vessels. A certain proportion of the lifebuoys carried must be fitted with self-igniting lights, but calcium lights are not permitted for the lifebuoys of tankers, and these must have electric battery-operated lights.

A typical lifebuoy placed in a chute in the bridge wing of a passenger liner is shown in fig. 5–4. This lifebuoy can be released by remote control and carries with it a Wessex Manoverboard marker, which consists of a smoke candle with two electric lights mounted diametrically opposite each other on top of the float. Both the lights and the smoke candle are operated by water-activated batteries. By day the marker emits a cloud of vivid orange-coloured smoke for not less than 20 minutes, and by night the lights burn for not less than two hours.

Buoyant apparatus

This apparatus can be of any approved shape so long as it conforms to the requirements for construction and material. A typical stack of buoyant apparatus on the deck of a passenger liner is shown in fig. 5–5. Each one is usually made

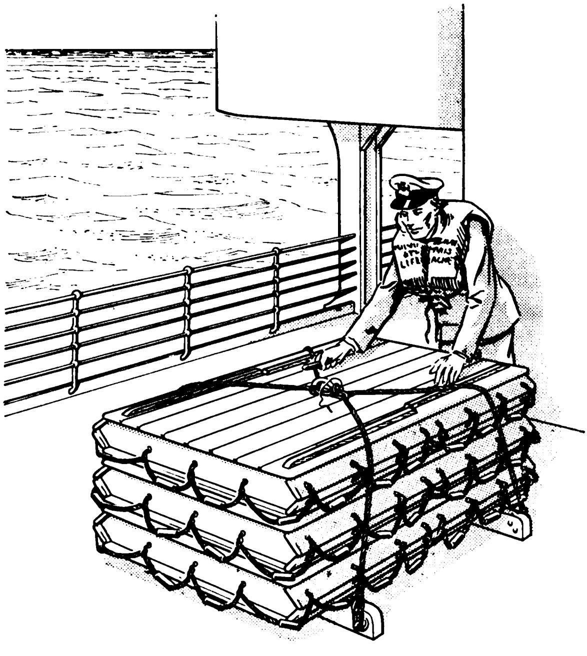


FIG. 5–5. Stack of three buoyant apparatuses in a passenger liner

of wood and incorporates metal buoyancy tanks; such equipment is commonly seen on board passenger ships, ferries, cross-Channel steamers and pleasure craft. The requirement in general is as follows:

1. It can be thrown into the water without being damaged.
2. It will float clear of the ship if she founders.

3. It must not exceed 400 lb in weight unless suitable means are provided to enable it to be launched without lifting it by hand.
4. It must be effective and stable when floating either way up.
5. It must be fitted with a painter and have a line securely becketed round the outside.
6. It must not carry more persons than the regulations permit. This number is found by dividing the number of pounds of iron it can support in fresh water by 32, or is equal to the number of feet in the perimeter, whichever is the less.
7. Its buoyancy must not be dependent upon inflation.

Passenger ships engaged on international voyages may in some cases carry buoyant apparatus for 25 per cent of the total number of persons on board, but generally they carry buoyant apparatus to accommodate 3 per cent of all persons on board. Passenger ships engaged on short international voyages must carry buoyant apparatus for at least 5 per cent of the total number of persons on board.

Rigid liferafts

This type of liferaft must be so constructed that when dropped into the water from its normal stowed position neither the liferaft nor its equipment will suffer damage. The equipment is stowed so that it is readily available whichever way up the liferaft is floating. There is a cover, of a highly visible colour, which affords protection from exposure to the occupants. The weight of a rigid liferaft and its equipment carried in passenger ships must not exceed 400 lb; though in cargo ships, if means are available for launching such rafts from both sides of the ship or putting them into the water mechanically, they may exceed this weight. There is a painter and a lifeline securely becketed round the outside and the inside of the raft. There must also be, at each opening, efficient means to enable people in the water to climb on board; arrangements enabling the raft to be towed; and a buoyant light of the electric battery type attached to it by a lanyard. These liferafts are stowed so that they will float free of the ship if she founders. Rigid liferafts are seldom found in the British Merchant Navy.

Ships may be allowed a certain percentage of their lifesaving complement to be made up of liferafts, of either rigid or inflatable construction. An indication of the numbers which must be carried is given in the next paragraph.

Inflatable liferaft

This type of liferaft is similar to the naval inflatable described in Volume II. The main differences are that the survival equipment is stowed within the liferaft and not, as in the naval liferaft, in a separate survival pack; the requirements of equipment are on a different scale; the rafts may be designed to accommodate from six up to twenty-five persons; and the total weight of the liferaft, its equipment and valise, must not be more than 400 lb. At the present time there are two types in use in the Merchant Navy:

1. an oval-shaped raft of similar design to the R.N. 20-man raft, for launching over the ship's side;
2. a circular raft that can be launched either from a davit or crane, or over the ship's side. A circular inflatable liferaft of the second type, capable of carrying 20 persons, is shown in fig. 5–6.

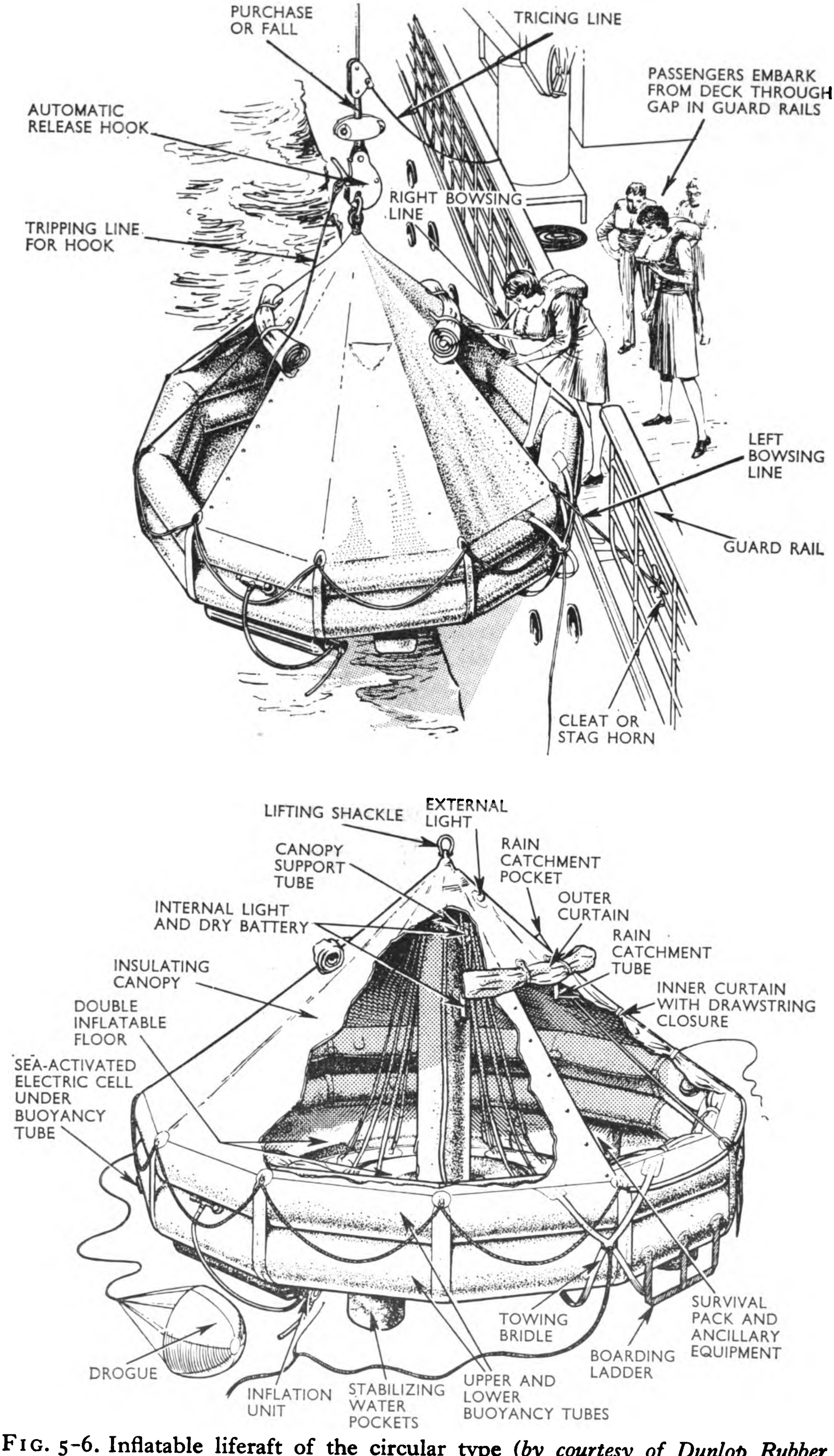


FIG. 5-6. Inflatable liferaft of the circular type (*by courtesy of Dunlop Rubber Company Ltd.*)

Passenger ships engaged on international voyages may be permitted to substitute 25 per cent of their lifeboats for liferafts of the same total carrying

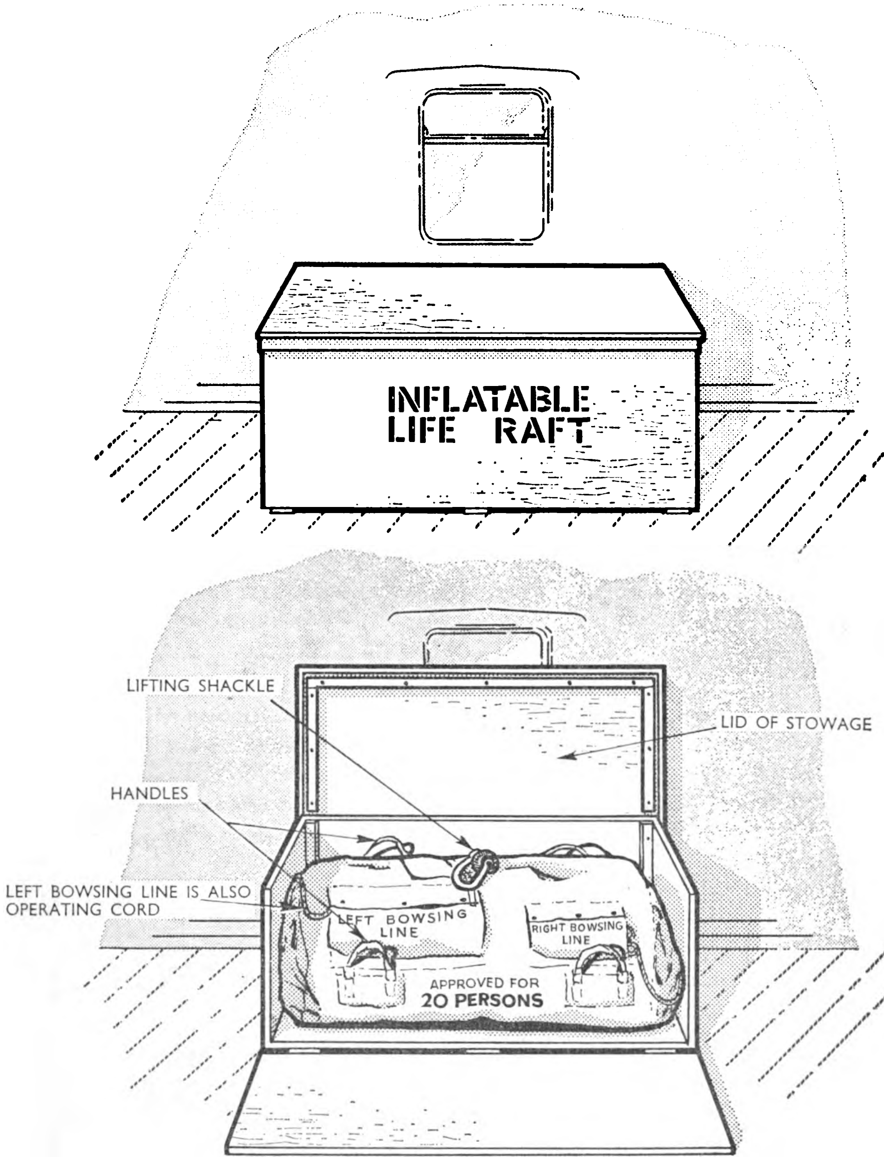


FIG. 5–7. Inflatable liferaft in a typical stowage (*by courtesy of Dunlop Rubber Company Ltd.*)

capacity, but must nevertheless always carry in addition liferafts to accommodate 25 per cent of all persons on board.

Passenger ships engaged on short international voyages, if the lifeboats of the ships are not sufficient to accommodate every person on board, must carry in

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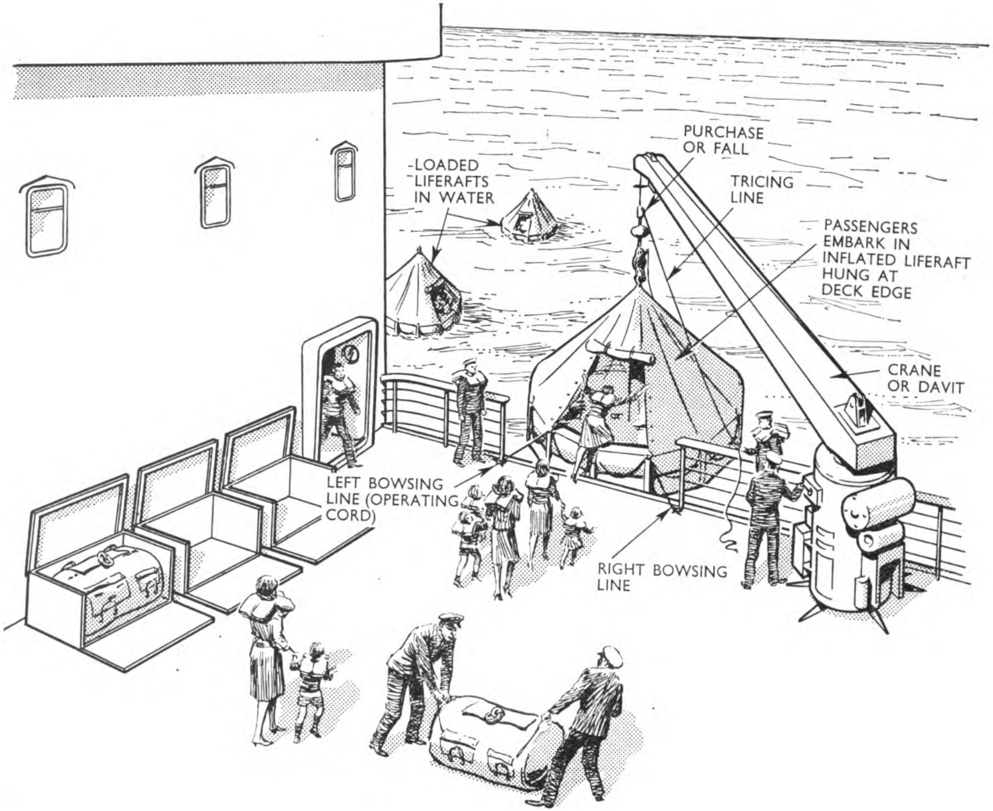


FIG. 5–8. Embarkation into inflatable liferaft to be lowered by **crane** (***by courtesy of Dunlop Rubber Company Ltd.***)

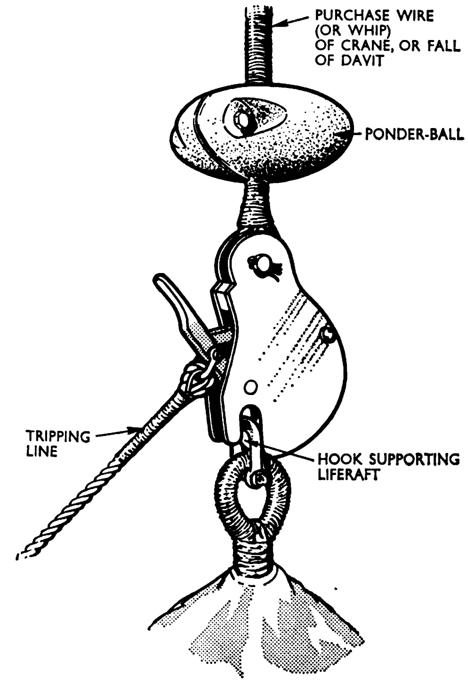


FIG. 5–9. The Mills 'Atlas' quick-release hook for a liferaft when lowered by crane

addition liferafts to accommodate the remainder of the persons. Nevertheless, whatever the ratio is between lifeboats and liferafts carried, the ship must carry additional liferafts sufficient to accommodate 10 per cent of the persons for whom there is lifeboat accommodation provided.

The international regulations also lay down scales of liferafts to be carried by cargo ships, tankers and whale or canning factory ships. The rules are somewhat complex, but the aim is to ensure that there is either lifeboat or liferaft capacity for every person on board, plus a spare capacity to allow for lifesaving apparatus that has been damaged in an emergency.

The equipment to be provided in rigid and inflatable liferafts is similar to that required in the R.N. inflatable liferaft, and details are given in the international rules.

An inflatable liferaft is shown in fig. 5–7 in a typical stowage on the deck of a passenger ship. A method of lowering a number of liferafts rapidly by crane is illustrated in fig. 5–8. First, each liferaft is dragged from its stowage to a position under the crane (or davit). The bowsing lines are secured to suitably placed cleats or staghorns, or to the guardrails. The raft is then hooked on, and hoisted up by the crane. This action tautens the left bowsing line (which is also the operating cord), and so causes the raft to inflate automatically. The fall is hoisted to a mark which is so placed that the raft will come level with the deck after inflation. Passengers embark at deck level as soon as the raft has been bowsed in securely. The crane remains swung outboard, and the fall is recovered after each lowering by a tricing line.

Usually the crane hook is of a special type that will release the raft immediately it becomes waterborne. An example of this type of hook is shown in fig. 5–9. When the passengers are embarked, the man in charge in the raft pulls the tripping line, thus actuating the automatic release mechanism of the hook. This must not be done until the bowsing lines have been cast off, otherwise a passing wave might release the raft prematurely. The raft is now lowered to the water and there releases itself.

Lifeboats

The detailed specifications for the construction and fitting of lifeboats on board merchant ships are laid down in the U.K. by the Ministry of Transport, who follow the general specifications which are contained in the rules of the International Conference on Safety of Life at Sea. In this section a general description only is given, to show broadly what types of lifeboats are fitted and how they are equipped and used.

Classification of boats. Lifeboats are propelled by either oars, sail, mechanical power, or by a compression-ignition engine. Those propelled by mechanical power or by an engine need not carry a mast or sails or more than half the usual complement of oars, but they must carry two boat-hooks.

Stability and buoyancy. Every lifeboat must have ample stability in a seaway, and adequate freeboard when loaded with its full complement of persons and equipment. It must have rigid sides and be fitted with internal buoyancy only. The Ministry of Transport may approve lifeboats with a rigid shelter, but it must be possible to open the shelter from both the inside and outside, and the

shelter must in no way impede the rapid embarkation, disembarkation, launching or handling of the lifeboat.

All lifeboats have inherent buoyancy, or are fitted with watertight buoyancy tanks or compartments, sufficient to float the boat and its equipment when the boat is flooded and open to the sea. Additional buoyancy equal to at least one-tenth of the cubic capacity of the boat must also be provided. Buoyancy tanks or compartments may be filled with a buoyant material which must not be adversely affected by oil.

Size. No lifeboat is approved which exceeds 20 tons when loaded with its full complement of persons and equipment, or which has a carrying capacity of more than 150 persons. A typical large motor lifeboat to carry 145 persons is shown in fig. 5–10. Every lifeboat that can carry from 60 to 100 people must be either a motor lifeboat or a lifeboat propelled by mechanical means. Lifeboats that carry more than 100 persons must be motor lifeboats.

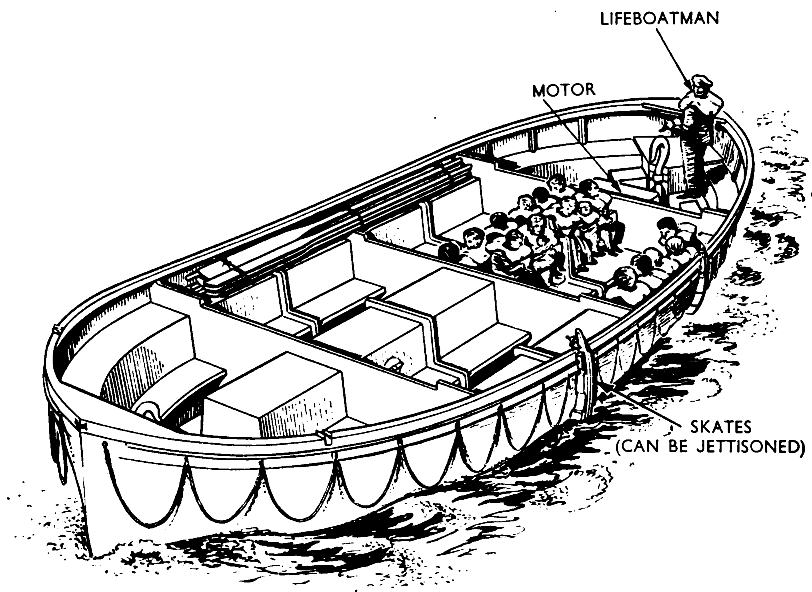


FIG. 5–10. Typical large motor lifeboat of a passenger liner. The maximum size allowed is a 20-ton boat and the maximum number of passengers 150.

Propulsion. A motor lifeboat is fitted with a compression-ignition engine. The engine must be kept so that it is ready for use at all times and can be started in all conditions, and must be fuelled for 24 hours' continuous running at a speed of at least six knots (fully loaded) when carried on board passenger ships, tankers, or whale or canning factory ships; and at least four knots if carried in other types of ship. The engine must be protected adequately from the weather, and the engine casing must be fire-resisting.

A mechanically propelled lifeboat is fitted with propelling gear of sufficient power to enable the lifeboat to be cleared readily from the ship's side when launched and to be able to hold course under adverse weather conditions. If

the gear is manually operated it must be capable of being operated by anybody and must be workable when the lifeboat is flooded. A device must be fitted to enable the boat to go astern at any time when the propelling gear is in operation. A common form of manual propulsion is by means of levers placed between the thwarts. When worked forward-and-aft the boat is propelled through the water (fig. 5–11).

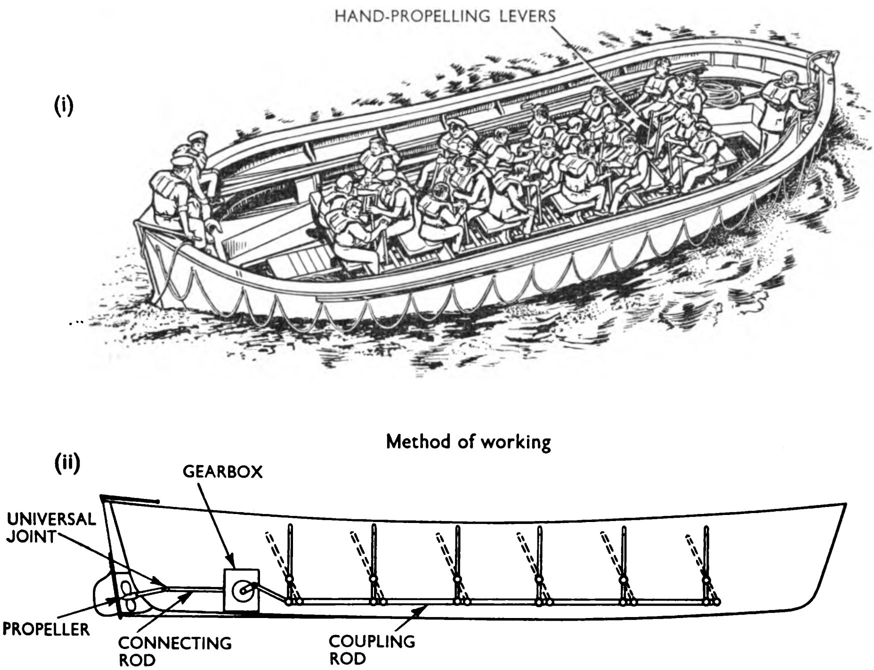


FIG. 5–11. Hand-propelled lifeboat

Number of lifeboats carried. The regulations lay down the minimum complement of lifeboats which are to be carried on board various types of ships. Some ships are permitted to substitute liferafts for a proportion of their lifeboats, while others are required to carry a greater proportion of lifeboats for the number of persons on board. For example, a cargo ship if damaged will list heavily because of its large cargo spaces and is therefore required to carry sufficient lifeboats on *each* side of the ship to accommodate *all* the persons on board, while a passenger ship is only required to carry sufficient lifeboats on *each* side of the ship to accommodate *half* the number of persons on board. In passenger ships there must be normally at least one motor lifeboat, fitted with a searchlight and radio transmitter, on each side of the ship.

Emergency lifeboats. There must be one boat on each side of the ship kept ready for immediate use while the ship is at sea. These must be of an approved type and not more than 28 ft in length. If they comply fully with the requirements for lifeboats or motor lifeboats they may be counted as part of the lifeboat or motor lifeboat complement.

Stowage of lifeboats. Every lifeboat is normally hoisted at a separate pair of

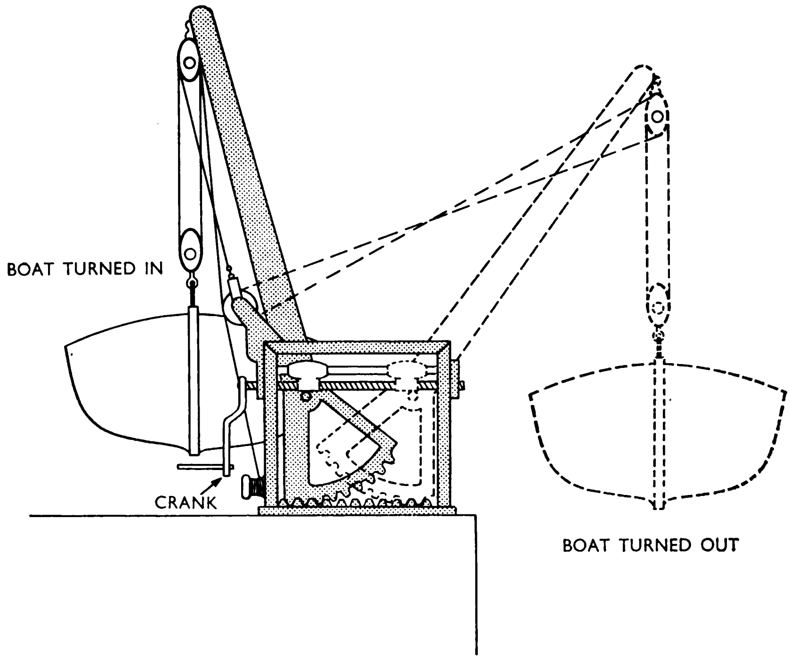


FIG. 5–12. Luffing-type davits

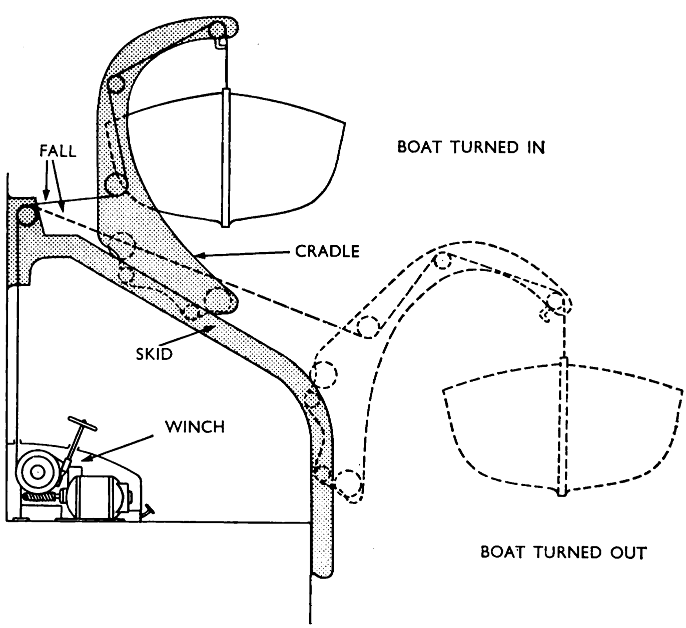


FIG. 5–13. Gravity-type davits

davits, and lifeboats may only be stowed on more than one deck if proper measures are taken to prevent lifeboats on a lower deck being fouled by those stowed on a deck above.

The *luffing* type of davit (also known as the *quadrantal* davit), one type of which is illustrated in fig. 5–12, is canted outboard by means of a crank handle. The *gravity* type davits (fig. 5–13) are made in two parts, the fixed part being called the *skid* and the movable part the *cradle*. The cradle, which supports the boat, is mounted on rollers and can move up or down the skid, and both cradle and boat are slung on a single-part fall rove round sheaves and led to a power-operated winch. When the brake of the winch is released the cradle with the boat moves by gravity down the skid, which is so shaped that at the lower end of its travel the cradle cants outboard and so places the boat into a position ready for lowering.

In tankers of 1600 tons gross tonnage and upwards, and in whale or canning factory ships, all davits must be of the gravity type. In all other ships the davits must be either of the luffing or gravity type for operating lifeboats which weigh less than 2¼ tons in their turning-out condition; or of the gravity type for operating lifeboats which weigh more than 2¼ tons.

Skates are usually fitted to the inboard side of each lifeboat to enable it to slide down a listed ship's side as it is lowered, without suffering undue damage. When the boat is waterborne the skates are unclamped and jettisoned (fig. 5–14).

Lifeboats normally have wire falls, together with winches which, in the case of the emergency boats, must be capable of quick recovery of these boats. The Ministry of Transport may permit in exceptional cases manila or other approved material to be used for the falls. At least two lifelines must be fitted to the davit span, and the falls and lifelines must be long enough to reach the water with the ship at its lightest sea-going draught and listed 15° either way. The lower blocks of the falls have a suitable ring or long link for securing the blocks to the sling hook, unless there is disengaging gear fitted.

Typical lowering and embarkation arrangements for a large lifeboat in a passenger liner are illustrated in fig. 5–14. It will be seen that there is a simple and efficient arrangement for bringing the boat close in against the ship's side so that people can be embarked safely from deck level. The method shown requires a bowsing-in pendant and tackle at each end of the boat. The upper end of the pendant is secured to the davit at 2A (fig. 5–14), the lower end to a lug on the lower block of the fall (2B). When the boat reaches deck level at the boat station (where passengers embark) the pendant tautens, takes the boat's weight and bowses her in to the ship's side (position 3). Bowsing-in tackles are then rigged from the ship's side to another lug on the fall block and hauled taut. Passengers now embark and the lower end of the pendant is unshipped by means of a slip. When the boat is ready, the tackles are eased out and unshipped and the boat lowered (position 4).

Portable radio apparatus. An approved portable radio apparatus for survival craft is carried on board every ship which does not carry on each side of the ship a motor lifeboat fitted with radio. This portable apparatus is kept available in the chartroom or other suitable place ready to be moved to one or other of the lifeboats in an emergency.

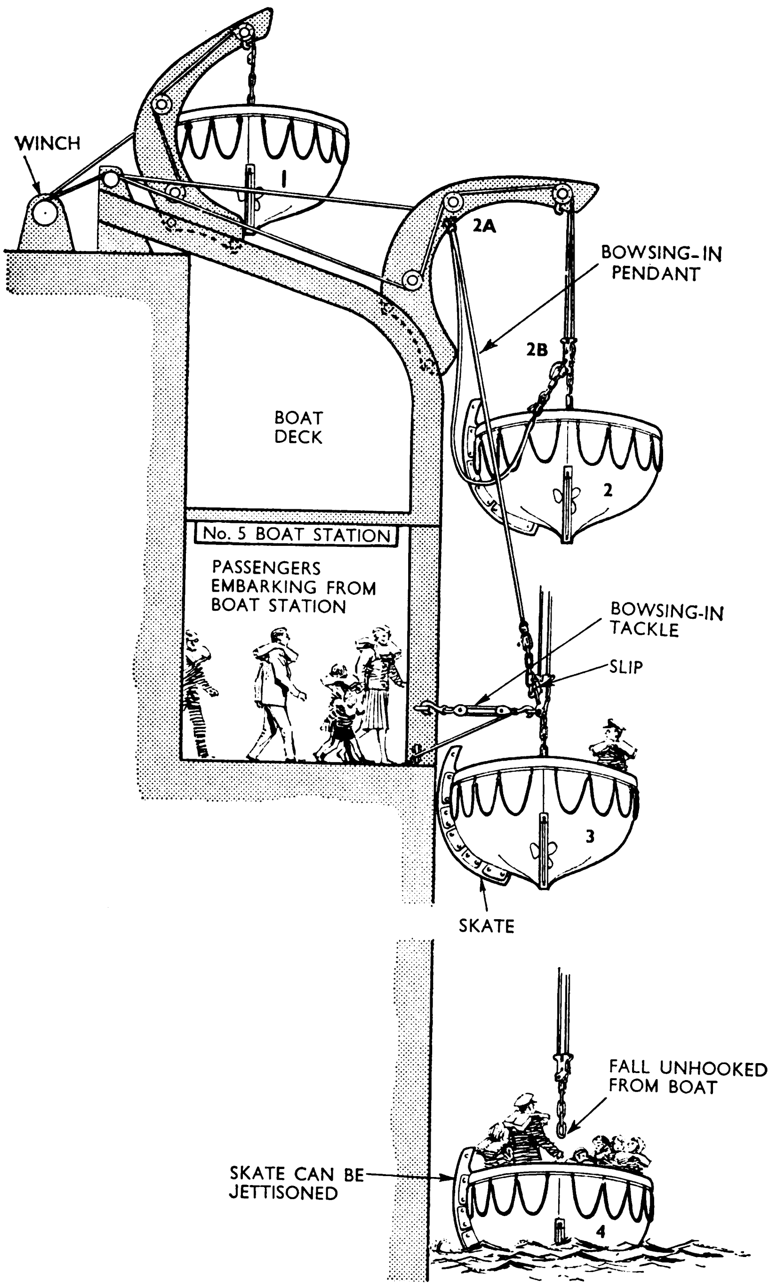


FIG. 5-14. Lowering and embarkation arrangements for a large lifeboat in a passenger liner

Equipment of lifeboats. The equipment to be carried is laid down in detail in the international regulations. In addition to the normal equipment of a sea-boat such items as follow are specified.

1. A lifeline to be becketed round the outside of the boat; and also means to enable people to cling to the boat should it capsize.
2. Food and water rations, to be carried in special airtight and watertight containers.
3. Distress signals such as red flares, parachute rockets and orange smoke signals; and a daylight-signalling mirror, electric torch and whistle.
4. A certain proportion of motor lifeboats in passenger ships are required to carry radio transmitters and searchlights.
5. Fire-extinguisher and first-aid outfit.
6. Mast and outfit of orange-coloured sails (this is not obligatory for motor lifeboats).

The equipment must be placed and secured in the boats before the ship proceeds to sea.

Certificated Lifeboatmen

A Certificated Lifeboatman is a seaman who holds a certificate issued by the Ministry of Transport to the effect that he has passed an examination in all the operations connected with launching lifeboats and other lifesaving appliances, in the use of oars and propelling gear and in the practical handling of lifeboats and of other lifesaving equipment.

The crews of all passenger ships include such men, the number depending upon the number of lifeboats carried and the prescribed complement of each boat. The following table shows the minimum number of lifeboatmen who must be included in the complement of each boat carried.

Prescribed Complement of Lifeboat	*Minimum Number of Certificated Lifeboatmen*
Less than 41 persons	2
From 41 to 61 persons	3
From 62 to 85 persons	4
Above 85 persons	5

Practice muster and drills

In passenger ships the crew is normally exercised weekly for boat drill and fire drill, and must also be exercised when the ship leaves the final port of departure on an international voyage. There must be a muster of the passengers at their respective boat stations within twenty-four hours of a ship leaving port when on an international voyage.

Different groups of lifeboats are used in turn at successive boat drills, and every lifeboat should be swung out and lowered at least once every four months.

The inspections of the lifeboats and their equipment are so arranged that the crew are practised in the duties they have to perform, including the handling of liferafts if carried.

In cargo ships the crew is mustered for boat drill and fire drill at least once a month, and, if more than 25 per cent of the crew have been replaced, within twenty-four hours of leaving port. At the monthly muster all the lifeboats' equipment is examined to make sure that it is complete.

The emergency signal for summoning passengers to muster stations is a succession of seven or more short blasts followed by one long blast on the ship's whistle or siren. In passenger ships on international voyages this signal must be supplemented by other electrically-operated signals throughout the ship and operable from the bridge. The meaning of all signals affecting passengers, with precise instructions on what they are to do in an emergency, is clearly stated on cards pasted in their cabins and in conspicuous places in other passenger quarters.

Crew muster list and emergency procedure. Before a vessel sails a muster list is drawn up and copies posted about the ship, and in particular in the crew's quarters. It shows the special duties allocated to each member of the crew in an emergency and the station to which he must go. These special duties include the closing of watertight doors, valves, scuppers, ash-shoots and fire doors; the equipping of the lifeboats and the other lifesaving appliances, including the portable radio apparatus for survival craft; the launching of the lifeboats; the general preparation of the other lifesaving appliances; the muster of the passengers; and the extinction of fire.

The special duties assigned to members of the stewards' department include warning the passengers, seeing they are suitably dressed and have put on their lifejackets in the proper manner, assembling them at muster stations, keeping order in the passages and on the stairways, and ensuring that a supply of blankets is taken to the lifeboats.

Before leaving harbour a British passenger liner normally musters all her crew and exercises them in their various damage-control and lifesaving duties. In the U.K. a Ministry of Transport Marine Surveyor is usually present and checks that the various members of the crew know exactly what would be expected of them in an emergency.

Manning of lifeboats and liferafts

Each lifeboat normally has a deck officer or Certificated Lifeboatman in charge of it and a second-in-command is also nominated. The person in charge should have a list of the lifeboat's crew and must ensure that they are acquainted with their duties. One of the lifeboat's crew must be capable of working the engine if the boat is a motor lifeboat, and one of working the radio and searchlight installation if carried.

Embarkation into lifeboats and liferafts

Suitable arrangements must be made for embarkation into the lifeboats and liferafts, consisting of a ladder or some such suitable device at each set of davits, and sufficient ladders at the launching positions to enable people to join the lifeboats or liferafts when they are waterborne. There must be adequate

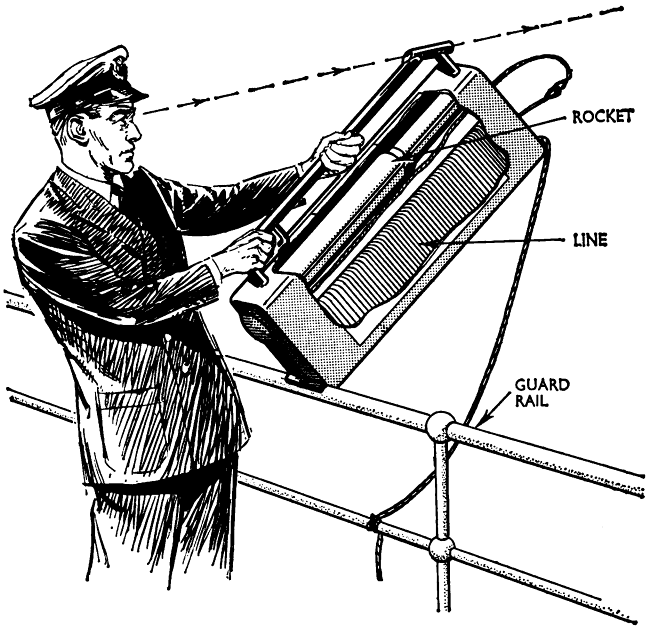


FIG. 5–15. 'Wessex' self-contained rocket line-thrower

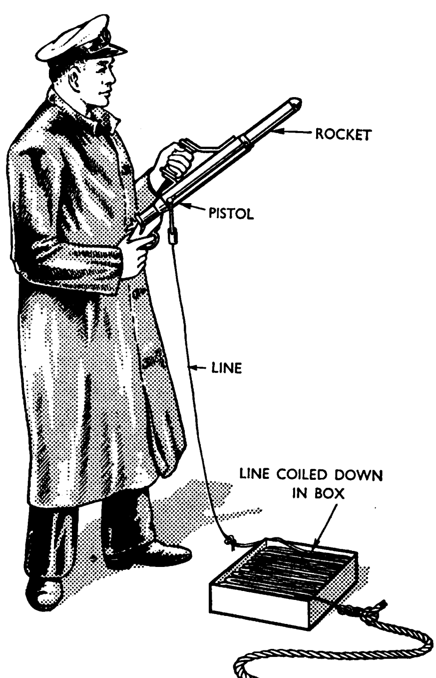


FIG. 5–16. 'Schermuly' pistol rocket apparatus

illumination at the davit and liferaft stowage and embarkation positions and also of the water during the launching until the operation is completed; arrangements for warning the passengers and crew that the ship is about to be abandoned; and means for preventing any discharge of water into the lifeboats, and into liferafts at fixed launching positions, including those under launching devices. There must also be an emergency lamp kept continuously lighted at the exit from each main compartment in the ship occupied by passengers or crew.

Line-throwing appliances

Every ship carries a line-throwing appliance capable of throwing a line a minimum distance of 250 yards in calm weather with reasonable accuracy, and the apparatus must include at least four lines and four projectiles, the lines having a minimum breaking stress of 250 lb.

The lines and projectiles, together with a copy of directions for use of the appliance, should be stowed in a watertight case. The Wessex and Schermuly line-throwing appliances are illustrated in figs. 5–15 and 5–16 respectively.

ROCKET LIFESAVING APPARATUS

Lifesaving stations

Numerous lifesaving stations are established round the coasts of Great Britain and Northern Ireland for rescuing shipwrecked mariners or assisting vessels in distress by means of lifeboats or the rocket lifesaving apparatus. Those which are rocket lifesaving stations are administered by the Ministry of Transport (H.M. Coastguard), and their situations, together with details of the assistance they can afford, are given in the relevant volume of the *Admiralty Sailing Directions*.

Because this apparatus is used for rescuing a crew of a ship stranded close inshore, it is usually provided at those stations which are situated in the vicinity of cliffs or high land, and in other places where a lifeboat cannot get close inshore.

Description and method of operation

The apparatus comprises a rocket and line, a tail-block rove with an endless whip, a jackstay (which is described in some publications as the *hawser*) and traveller, and a breeches buoy. The rocket, which is secured to a one-inch line of tarred hemp 250 fathoms in length, has a range in still air of 450 yards; it is fired from the shore and aimed to pass over the ship. When the rocket-line has been secured in the ship a tail-block, through which is rove an endless whip of 1½-inch manila, is hitched to its shoreward end.

If a particularly heavy gale is blowing directly onshore initial connection may be made by the ship firing a line to the shore; the rescuers then hitch a stouter line to the ship's line, and, when the crew has hauled it on board, the tail-block and whip are hitched to the stouter line.

The crew of the ship haul in the rocket-line, tail-block and whip, and then secure the tail-block to the mast or superstructure as high up as is conveniently practicable, bearing in mind that the jackstay, when passed, must be secured at a point two or three feet above the tail-block (fig. 5–17).

The jackstay is of 3-inch manila, 120 fathoms in length, and has a becket spliced into it a few feet from the end. One part of the endless whip is hitched to the jackstay by reeving its bight through the becket and making a clove hitch on the bight round the jackstay. When the tail-block has been secured on board, the rescuers haul the end of the jackstay out to the ship by means of the endless whip.

When the end of the jackstay is hauled on board it is brought up between the two parts of the endless whip and secured to a point two or three feet above the tail-block. The whip is then unhitched from the jackstay, care being taken that the whip is clear of the jackstay and free to run through the tail-block.

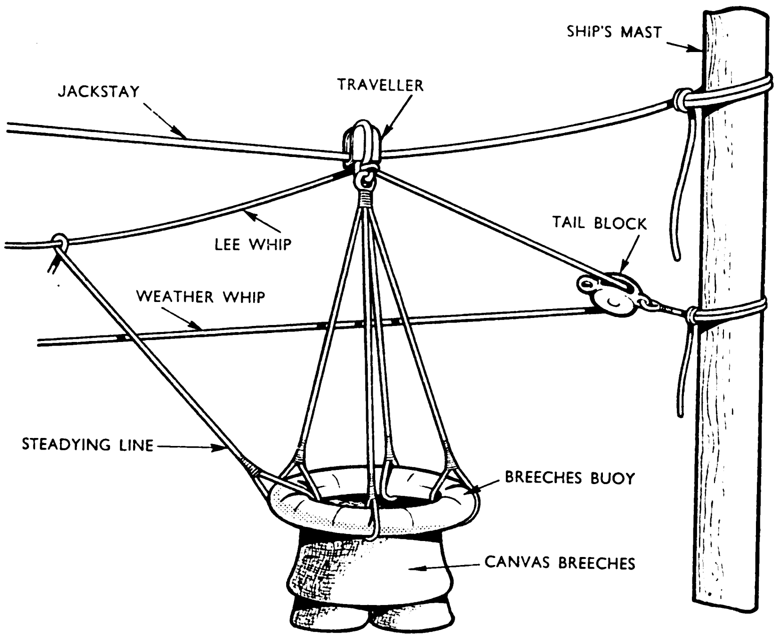


FIG. 5–17. Rocket lifesaving apparatus

The rescuers then set the jackstay up taut, fit the inverted single block, which forms the traveller, on the jackstay, and bend the bight of the endless whip to the becket of the traveller. The out-haul part of the endless whip is called the *weather whip* and the other part the *lee whip*.

The breeches buoy, which is a Kisbie buoy fitted with a four-legged sling and a divided canvas trunk in the form of a pair of breeches, is slung on the traveller, and a steadying line is rigged from the shore side of the buoy to the lee whip. The traveller with the breeches buoy is then hauled out to the ship by the weather whip.

The first member of the crew to be rescued then steps into the breeches of the buoy, facing shoreward, and steadies himself by grasping the steadying line; the rescuers then haul the buoy ashore by the lee whip. This operation is continued until all the crew are rescued.

Signals for operating

Each stage of the operation should be indicated by a signal.

By day. The signals made from both shore and ship consist of the horizontal or vertical movement of a white flag. The meanings of these two movements are given below. In the ship a man should be detailed to stand clear of the remainder of the crew and to wave the flag; or, if one is not available, to wave his arm or his cap. An alternative signal is to fire either a green or a red star signal.

By night. The signals from both shore and ship consist of the horizontal or vertical movement of a white light, or alternatively the firing of a green or red star signal.

If the signal is made by waving with a vertical motion (up and down), or if a green signal is fired, its general sense is *affirmative*, e.g. 'Haul away', 'Line made fast'; but if it is made by waving horizontally (from side to side) or a red signal is fired, its general sense is *negative*, e.g. 'Avast hauling', 'Slack away'.

In poor visibility the signals may be made in the ship by giving a short blast on the siren, foghorn or whistle, and they may be made on shore by firing a sound rocket or blowing a whistle.

The various stages which should be indicated by signal are as follows:

In the ship: when the rocket-line is in hand;
when the tail-block is secured;
when the jackstay (hawser) is secured;
when a man is ready to be hauled ashore in the breeches buoy.

On shore: when the tail-block is hitched to the rocket-line and ready to be hauled on board.

In addition to these signals, communication by flashing or hand flags should be established between ship and shore whenever possible; in most rescue crews there is a trained signalman.

PART II

SEAMANSHIP

CHAPTER 6

Towing at Sea

Taking a ship in tow, and preparing to be taken in tow, are both commonly practised evolutions in warships. The need to take a disabled ship in tow may occur suddenly in peacetime and perhaps more frequently in wartime. How to prepare the necessary gear on the upper deck, how to pass and secure the tow, and how to slip and recover it, are described in Volume II.

It is obvious, however, that no rigidly standard method of towing or being taken in tow can be laid down, because the method used will depend on the types of ship involved, the condition of the towed ship, the duration of the tow, and such other matters as the urgency of the situation, the weather and the route to be taken. This chapter deals with the subject as a problem in shiphandling, and is also intended to help the Captain and his assistants on the bridge to select the gear and method best suited to the situation. Shiphandling generally is dealt with in Part IV.

Comparison between warships and rescue tugs

Generally speaking, the average warship compares unfavourably with a properly equipped salvage tug for the purpose of towing. Ocean-going tugs have certain features in common. First, they are as small as is consistent with good sea-keeping qualities and adequate power and endurance. A short, squat ship is handy at slow speed in a seaway; moreover the towing deck is under the direct control of the bridge, and the distance between forecastle and towing deck is so short that a head-on approach when passing the tow can be adopted if circumstances require it. Secondly, the rescue tug is often single-screwed, with an overhanging and well-padded counter; if twin-screwed, she is fitted with efficient rope guards. Thirdly, the tug has a low towing deck, probably with a self-tensioning winch or a shock-absorbing towing hook fitted near the centre of gravity, and with overhead towing horses to provide a clear run for the gear.

Warships in general are the antithesis of the salvage tug in all these respects, and the problem is aggravated by their widely-differing handling characteristics. But these handicaps can be minimised by skilful shiphandling, and on many occasions ships of the Royal Navy have carried out successful tows in most difficult circumstances over long distances.

Taking in tow

To recapitulate briefly the process of taking in tow (as described in Volume II), a typical sequence of events would be as follows, assuming the ship to be towed is able to prepare the towing gear. The wire towing hawser is laid out on the forecastle, with its inboard end secured to the port cable. The outboard end of the towing wire is secured to one end of a manila hawser, the other end of which is secured to a coir hawser. The coir and the manila are both used as messengers to take across the heavy towing wire to the towing ship, and both are faked down ready for running on the forecastle of the towed ship.

The towing ship now approaches and establishes contact, by firing a gun line, for example. The towed ship secures this to the coir, and the towing ship hauls across the gun line, followed by the coir, then the manila and finally the towing wire, which she secures to a towing slip. The towed ship now veers a length of cable secured to the last end of the towing wire to act as a spring to take the shock of sudden stresses in the tow; and she secures the tow by setting her port cableholder at *brake-to-brake* and putting on a slip as a preventer. All is now ready for the tow to proceed.

The use of Nylon towropes is increasing. Nylon is much more elastic than wire, and therefore its use renders composite towropes unnecessary.

TOWING PREPARATIONS

In addition to making ready the towing gear (as described in Volume II) there are various preparations that may have to be made.

Communications

In the towing ship it is essential to organise good communication between the bridge and quarterdeck. It will be helpful to station on the quarterdeck an officer or senior rating whose sole duty is to pass a running commentary on the situation aft by telephone to the bridge. Some Captains may prefer to go aft themselves and to pass conning orders to the bridge by telephone. Good communication between the towing and the towed ship must also be organised by some means or another.

Propellers

When a ship is being towed the drag of each of her propellers may be as much as, or even greater than, the resistance offered by the underwater surface of her hull. The engines should therefore be disconnected from their shafts, when practicable, to allow the propellers to trail.

Radar reflectors

When it is intended to tow a small vessel, or one with very low freeboard such as a motor torpedo boat or small submarine, it is usually helpful to rig her with a mast fitted with a radar reflector. This will enable a check to be kept on her in low visibility, and help in her recovery if she breaks adrift or if the towrope has to be slipped in emergency.

Lights

A vessel may have to be towed for a long distance without a crew, and it may be impracticable to provide her with navigation lights which will burn throughout the duration of the tow. In these circumstances the towing ship should illuminate the towed ship at night by searchlight when in the vicinity of shipping.

All Admiralty-owned tugs are supplied with a set of propane-gas navigation lights for installing on unmanned towed vessels. These lights will burn continuously for a period of approximately six months.

Provision of electric power to a disabled vessel

If a damaged and disabled vessel is without steam and electric power it may be possible in calm or moderate weather to supply her by cable with sufficient electric power to enable her to pump out flooded compartments and correct any trim or list, provided that her electrical system is similar to that of the towing ship. On one occasion a destroyer in danger of sinking was made sufficiently seaworthy by this means to enable her to be towed to port. The cable should be in one continuous length, because it is very difficult at short notice to make a joint in electric cable sufficiently strong and watertight for this purpose. The end of the cable should be bound with tape to make it as watertight as possible, and the cable should be stopped in shallow bights, at intervals of three feet, to a 1¼-inch wire-rope jackstay, care being taken to parcel the cable at the stops to avoid chafe. If towing at long stay, the jackstay should be slung from the towrope by spring hooks at intervals of 5 to 10 fathoms.

APPROACH TO THE DISABLED SHIP

Maintaining position while passing the tow

The distance between the two ships should be kept as short as possible while the towing hawser is being passed and secured. The operation will be much more difficult if this distance is allowed to increase rapidly after first contact by line is made. For example, it will be a slow and painful procedure to haul in a heavy wire by hand if the distance exceeds 100 ft; while even with power available, as it normally is, the distance cannot be increased beyond about 300 ft without risk of parting the messenger.

Attitude and drift of the towing and the disabled ship

In any weather conditions other than glassy calm the nub of the problem of taking in tow lies in the fact that the disabled ship and the towing ship, unless they happen to be ships of the same class and are both undamaged, will almost certainly be drifting at different rates, and when stopped will be lying in different attitudes relative to the wind and sea.

Attitude of disabled ship relative to wind and sea

The direction relative to the wind and sea in which a ship will lie when stopped depends upon the position of her superstructure, her freeboard, the shape of the underwater part of her hull, and her trim.

If the ship is trimmed on an even keel the direction in which she will lie depends upon her freeboard and the arrangement of her superstructure. Ships with a high forecastle and a superstructure disposed well forward, such as tugs, will lie with the wind somewhat abaft the beam. Ships with their superstructure disposed more or less amidships, such as aircraft carriers, liners and some freighters, will lie broadside-on to the wind. Ships with their superstructure right aft, such as tankers, some bulk-freighters and some coastal vessels, may lie with the wind somewhat before the beam.

The more a ship is trimmed by the stern the farther will she lie off the wind; conversely, the more she is trimmed by the head the nearer will she lie to the

wind. The lighter a ship is laden the greater will be the effects of an uneven trim and the position of her superstructure. A deeply-laden three-island freighter will probably lie broadside-on to the wind, but the same ship in ballast, trimmed slightly by the stern to give adequate propeller immersion, will probably lie with the wind well abaft the beam.

Damaged plating projecting below the keel will have an effect similar to that of uneven trim, particularly if it is well aft or forward, because of the drag it offers to the drift of the ship to leeward.

Drift of a disabled ship

The speed at which a ship drifts to leeward depends upon the strength of the wind, her draught, her freeboard, and the area of her superstructure; and the more lightly laden she is the faster will she drift. A freighter, averagely laden, may drift in a gale at a speed of as much as 2 knots.

A ship lying with bow or quarter to the wind will tend to sail and so gather a little sternway or headway as she drifts; and this, combined with the effect of the waves, will make her yaw.

Assessing the situation

Time will probably be saved in the long run if the Captain of the towing ship, on first coming up with the disabled vessel, makes a careful and deliberate assessment of the attitude and drift both of the disabled vessel and of his own when stopped. It is therefore good practice to circle a disabled vessel at close range before approaching to pass a line. If uncertain as to how his own ship will lie and drift, he should stop her clear of the disabled ship and note her behaviour before attempting a close approach. If it is obvious that the rates of drift are going to be very different, e.g. a carrier intending to tow a deeply-laden tanker, then the Captain must impress on all the necessity to get the tow passed as quickly as possible, and must see that everything is fully prepared before passing the first line.

DIRECTION OF APPROACH—DRIFTING ATTITUDES SIMILAR

If the drifting attitudes and rates of the two ships are expected to be similar, the approach is best made on a slightly converging heading and aiming to pass very close across the weather bow of the disabled ship. There is little danger in a close approach under these circumstances, because the towing ship will make considerably less leeway as long as she is making headway (fig. 6–1). The course steered during the approach must take this fact into account.

The first lines can be passed from any position, but to avoid long leads of messenger and risk of fouling the propellers it will probably be easiest to pass from aft, as the towing ship's quarterdeck comes within range of the disabled ship's forecastle. As way is taken off the towing ship she should be manœuvred so as to take up position some 100 ft ahead of the other, and on the same heading, and one should try to hold her on this heading while the towing gear is being passed.

Should connection not be established when passing to windward of the disabled vessel, it may be difficult to regain a good position by making a stern-board and it will usually be more practicable to go right round and make another approach.

When the tow has been passed and secured, the towing ship should proceed slowly ahead on or near her present course while the gear is being paid out, and should not attempt to turn to the final course until the disabled ship is in tow. The alteration should then be made in very easy stages.

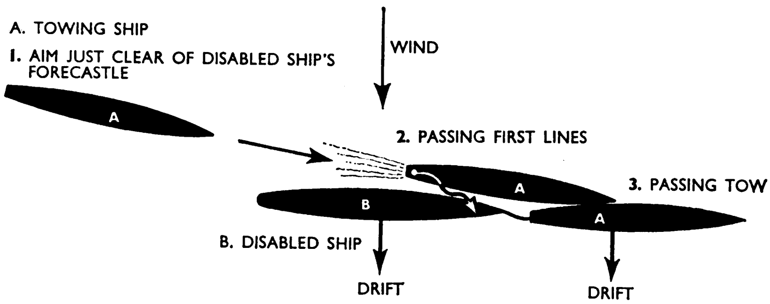


FIG. 6–1. Approach to a disabled ship—drifting attitudes similar

DIRECTION OF APPROACH—DRIFTING ATTITUDES DISSIMILAR

It may be the case that the towing ship is expected neither to assume the same drifting attitude as the disabled ship nor to drift at the same rate. In these circumstances a down-wind approach is usually preferable, because most men-of-war will steer quite well at slow speed with the wind astern unless there is a heavy following sea, whereas head-to-wind and -sea they are liable to pay off rapidly and uncontrollably as headway is lost. Furthermore this tendency to pay off when head-to-wind will be accentuated as sternway is gathered with the object of maintaining position on the drifting ship, whereas if approaching down-wind it will be comparatively easy to hold the stern up into the wind with slow astern revolutions while maintaining a slight drift to leeward. But the possibility of washing down the quarterdeck when going astern must be remembered. The following is an example of the down-wind approach.

Disabled ship lying broadside to wind

The towing ship should approach so that her course with the wind dead astern will lead her about 100 ft from the disabled ship's bows at the closest point (fig. 6–2). The greatest attention is required during the approach to ensure that own ship's path remains that distance ahead of her. If the other ship appears to be drifting ahead, and narrowing the estimated gap, it is not sufficient to alter a few degrees away, because a further alteration will almost certainly be required later, thus bringing the wind well on the quarter in the final stages. It will be better to elbow out so as to run down towards a position considerably further ahead.

The approach should be made at the slowest speed which will give good steering control. The precise moment and the method of passing the first line is a matter of seamanship on which individual opinions will vary. If the forecastle is considered the best place for the gun or heaving line, being under the direct control of the bridge, great care will be needed to keep the messenger clear of the propellers, while the ship moves ahead so as to take up a position slightly to leeward of the other's bows. No attempt to haul the towing gear across should be made until this position is reached.

There should be no great difficulty in maintaining a position just ahead and to leeward of the disabled ship's bow, provided she is drifting dead to leeward

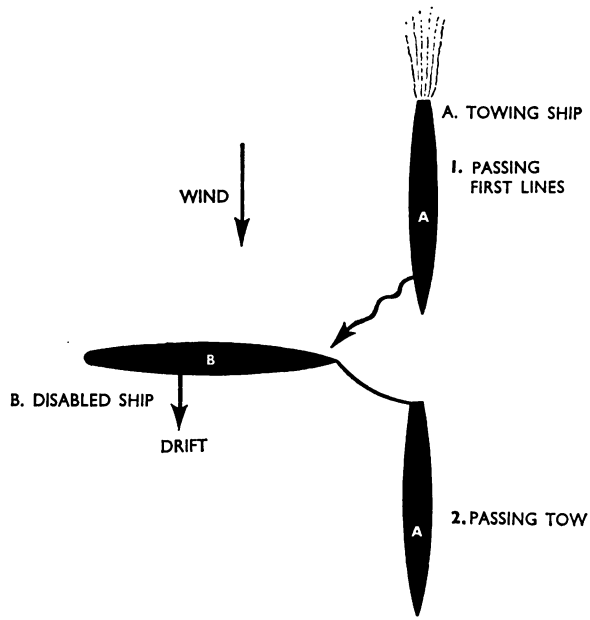


FIG. 6–2. Drifting attitudes dissimilar. Approach to a disabled ship lying broadside to wind

and assuming that propellers can be used, at any rate on the disengaged side. The towing ship should proceed slowly down wind while the gear is being paid out, and take the first strain while still nearly at right-angles to the other ship.

Disabled ship lying with wind abaft her beam

The disabled ship will be making headway and it will be dangerous to attempt to pass close across her bows, so that if a down-wind approach is made the towing ship must keep well ahead of the other in order not to risk collision (fig. 6–3).

By judicious use of the engines it should be easy enough to ensure that the disabled ship drifts close across the stern, and first connection should be made as this position is approached. If own ship's heading can subsequently be maintained in the direction of the other's drift, the operation of passing the tow should proceed normally; but if, as is more probable, own ship can only be maintained

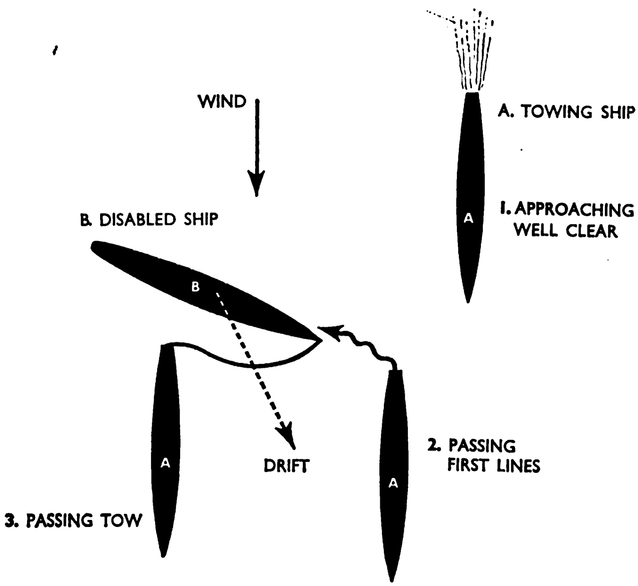


FIG. 6–3. Drifting attitudes dissimilar. Approach across the bow of a disabled ship with the wind abaft the beam drifting with some headway

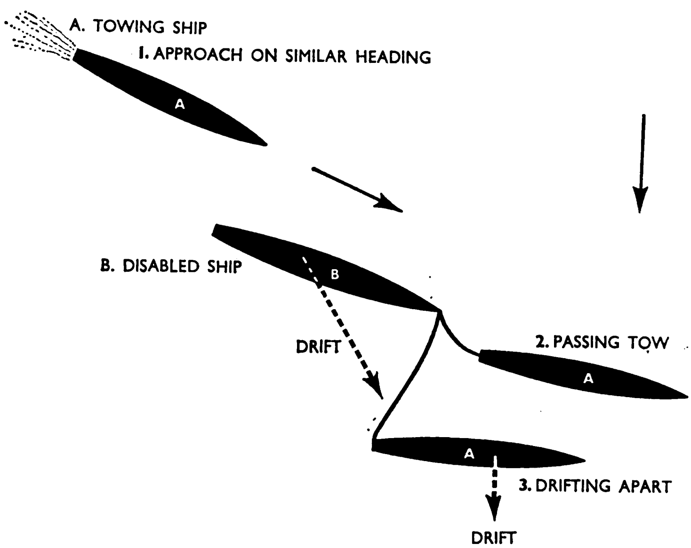


FIG. 6–4. Drifting attitudes dissimilar. Approach on a similar heading to a disabled ship drifting with headway with the wind abaft the beam

stern to wind, she will drift along the other's lee side and the handling of the gear may be difficult (fig. 6–3(3)).

If the tow is successfully hauled across and secured in spite of this relative drift, one should try to bring the towing ship on to a similar heading to the disabled ship while paying out, because unless a more forward position is attained the gear will be unfairly nipped and may part when the first strain is taken.

An approach on a similar heading to the disabled ship in these circumstances may therefore be preferable (fig. 6–4). When in position 2 the disabled ship's forward drift can be allowed for by the use of the towing ship's engines. However, if the rates and attitudes of drift of the two ships differ, the towing ship may soon find herself in position 3, with a rapidly widening gap that will hinder the passing of the tow.

Disabled ship lying stern to wind

If the disabled ship is lying with her stern directly up wind the problem is simplified. The towing ship can approach down wind on a similar heading and should have little difficulty in maintaining a position on one bow or the other while the tow is passed.

Disabled ship lying with wind before her beam

In this case the disabled ship will be making slight sternway, so that a close approach down wind can be made without danger (fig. 6–5).

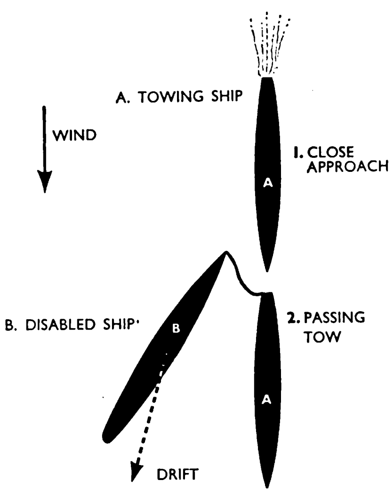


FIG. 6–5. Disabled ship lying with wind before her beam. Down-wind approach

Disabled ship lying bows to wind

If the disabled ship is holed forward and is well down by the bows she may lie practically head to wind. An approach down wind to a point abreast the disabled vessel (fig. 6–6) may expedite the passing of the first lines, but the towing

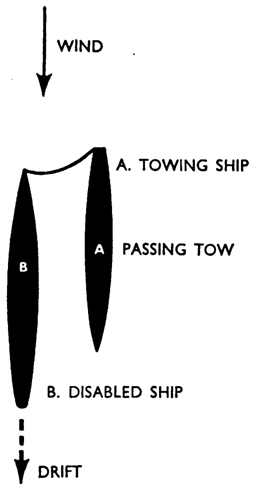


FIG. 6–6. Disabled ship lying bows to wind. Beam approach down wind

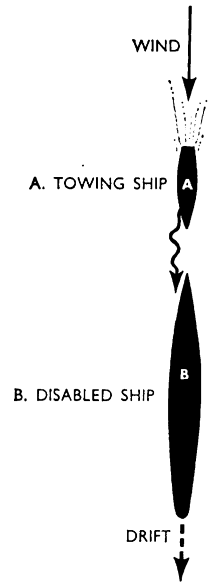


FIG. 6–7. Disabled ship lying bows to wind. Bow-to-bow approach by tug

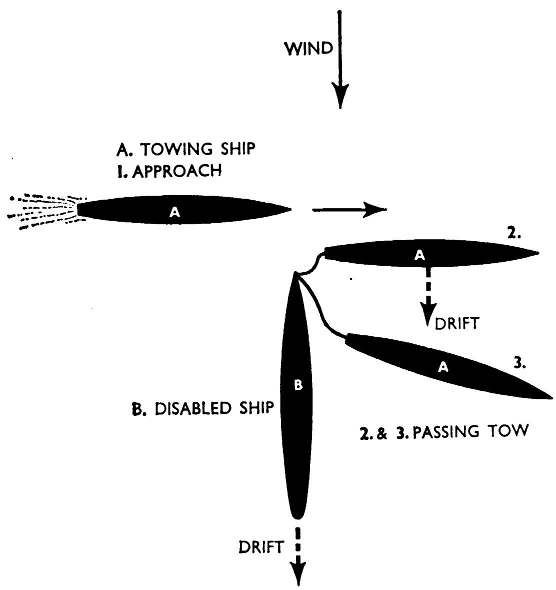


FIG. 6–8. Disabled ship lying bows to wind. Crossing approach by warship

ship will find it difficult to maintain her position while the tow is being passed, and even more difficult to move away to pay out the tow before taking the strain. In these conditions a tug would probably approach down wind bow-to-bow (fig. 6–7). Her handiness and the proximity of the towing deck to the bridge would assist such an approach, but the average warship would find it awkward to pass the tow from such a position. A man-of-war would probably find that to approach across the disabled ship's bows would be more effective (fig. 6–8). The tow would be passed as she drifts slowly down the side of the disabled ship.

The most obvious approach is into the wind and on a similar heading to the disabled ship, but this choice will almost certainly lead to trouble. The towing ship will fall off the wind as soon as her engines are put astern, and may then find herself across the disabled ship's bows and drifting rapidly on to her, possibly at a time when it is impossible to use the engines for fear of fouling the towing gear.

DISABLED SHIP TO BE TOWED STERN-FIRST

The shiphandling problem will not necessarily be any more difficult when the other ship has to be towed stern-first, though the operation of passing and securing the tow will often be more complicated.

In most cases the other ship will have been damaged forward and will be down by the bows. If this results in a head-to-wind attitude, a down-wind approach should enable position to be maintained quite easily while passing the tow, but great care will be required to keep own ship well clear of the other's exposed rudder and screws.

ESTABLISHING CONTACT

Use of boats or helicopters

Unless the disabled ship is short-handed or abandoned, boat work should be avoided as an unnecessary complication. The first line can be passed more quickly by gun or rocket, while in calm weather it is often possible to approach close enough for a heaving line to be used. Should these methods fail because of the weather conditions it is probable that boat work will also be impossible.

Warships that carry helicopters will find them invaluable as a means to carry across men and equipment to an abandoned vessel, but it is unlikely that they will prove any quicker as a means of carrying across the first lines.

By streaming a coir line

There are several different ways of establishing contact by streaming a coir line with its end bent to a small buoy, lifebuoy, or a cask. One is for the disabled ship to pay out the line from her weather side as she drifts to leeward; the line will then be streamed to windward of her, where it can be grappled and picked up by the towing ship. Alternatively, the towing ship can stream the coir line while under way and tow it so that it will lie to leeward of the disabled ship and in the path of her drift; then as the disabled ship drifts over the line she can grapple it and pick it up.

Another method is for the towing ship to bend the end of her coir line to a small target or a float rigged with a sail. She then stops to windward of the disabled ship, casts the target overboard and allows it to sail down wind to the disabled ship, carrying the end of the coir line with it.

Establishing contact by gun line

The remarks above on how to approach the ship to be taken in tow indicate generally at what stage to fire the gun line. It is usually easier to fire it from aft, so that it is close to the scene of operations. But if the tow is being provided by the towing ship the Captain may prefer to pass the gun line, and the coir and manila messengers, from the forecastle. He will then have an unobstructed view of the proceedings during the critical early stages when he is manœuvring his ship to get her as close as possible. Part of the last messenger must be prepared in this case by leading it aft from the forecastle, outboard of all, stopped at intervals to the gunwale, and then inboard through the towing fairlead on the quarterdeck, where it is secured to the towrope. If the ships are close enough, the Captain may decide to dispense with the coir and to use only the manila as a messenger.

Passing the tow

The work of passing and securing the tow is dealt with in Volume II.

SHIPHANDLING WHILE TOWING

Getting the tow under way

When the end of the towrope has been secured, the towing ship should move slowly ahead while veering the towrope to the required scope, and then stop while the towrope is finally secured in both ships. In shallow water be careful at this stage to keep the bight of the towrope off the bottom. The towing ship should then take up the tow, either by going ahead at the minimum revolutions possible (say, 20 in a steam-turbine ship) or by intermittent kicks of slow ahead if in a diesel ship, so as to subject the towrope as gradually as possible to the stresses of getting the towed ship under way. On reaching a speed of about two knots the engines can be kept moving continuously and speed be increased gradually until the required towing speed is attained. If Nylon towrope is used its great elasticity permits a practically horizontal pull to be applied safely, and the remarks in ensuing paragraphs about the need to keep the bight of the towrope immersed do not apply.

Great care and patience should be exercised when taking up a tow because the stresses involved in overcoming the inertia of the towed ship are much greater than those of towing her at a constant speed. The best way to judge the degree of stress in a towrope is to watch its catenary; the shallower the catenary the greater, of course, is the stress in the towrope, and it increases rapidly as the rope straightens out. The best practical rule for avoiding undue stresses in the towrope, both when taking up the tow and when towing, is never to allow its bight to break surface.

The direction in which the towing vessel should move off initially will be dictated to a certain extent by the relative attitudes adopted by the two ships

during the passing of the tow. If possible, she should move off on the heading of the towed ship, and only when satisfied that the tow is taking an even strain should she begin to alter course towards the intended destination. This alteration must be done gradually in steps each of a few degrees, allowing time after each step for the towed ship to come round to the new heading before altering to the next one.

Towing

Provided that the tow is riding comfortably astern and not yawing, there are no particular problems involved in towing. The bight of the towrope should be kept well immersed, and in a swell its length should be adjusted so that both ships rise together on the crests of the waves and fall together in the troughs. Keep the bight of the towrope off the bottom, because if it fouls the bottom both ships will be brought up with, perhaps, serious results, particularly if the towing course lies across the wind or current.

If the bight of the towrope shows a tendency to break surface, either the towrope should be lengthened or the speed of towing should be reduced. If the weather deteriorates the bight of the towrope should be immersed deeper, provided that there is a sufficient depth of water, and this is best done by veering cable. If there is insufficient water to increase the depth of the bight, speed should be reduced.

Any large alteration of course should be made in steps of a few degrees at a time, so that a steady strain is maintained in the towrope, otherwise its bight will sag and may foul the bottom.

Keeping the towrope intact

Once the tow is under way and turned towards harbour, the chief concern of both ships should be to keep the tow intact, since it is quite possible that neither ship (unless one is a salvage tug) will have a suitable replacement for the towrope if it parts. Often a parted tow cannot be recovered because, for example, of lack of facilities in the disabled ship. So no precaution that may help to preserve the tow should be neglected. The recovery of a parted tow, even if possible, is always arduous; and the time wasted on recovery and reconnection will be greater usually than that which might have been saved by forcing on at a higher speed than the circumstances warranted.

The condition of the towing gear must be kept under continuous observation in both ships and any signs of chafe or stranding remedied before a serious weakness develops. When chain cable is used at either end, the nip should be freshened at least once every twenty-four hours, speed being reduced during the process. The nip of a wire hawser requires more attention, and should be freshened more frequently. Fairleads and hawsepipes should be kept well greased, and hawsers should be parcelled well where they pass through fairleads and hawsepipes.

If the tow parts it is more likely to do so either close to the towing or to the towed ship. If, despite precautions, the towing ship foresees the probability of a parting near her own quarterdeck, she can secure a preventer rope to the towing hawser just outboard of the towing fairlead, as described in Volume II. The

inboard end of the preventer rope is faked down on the quarterdeck, with each bight secured to a lizard on a jackstay (fig. 6–9). If the tow parts inboard of the Carpenter's stopper, the preventer will act as a brake as it runs out; it should finally hold the tow, and can then be used to recover the towing hawser.

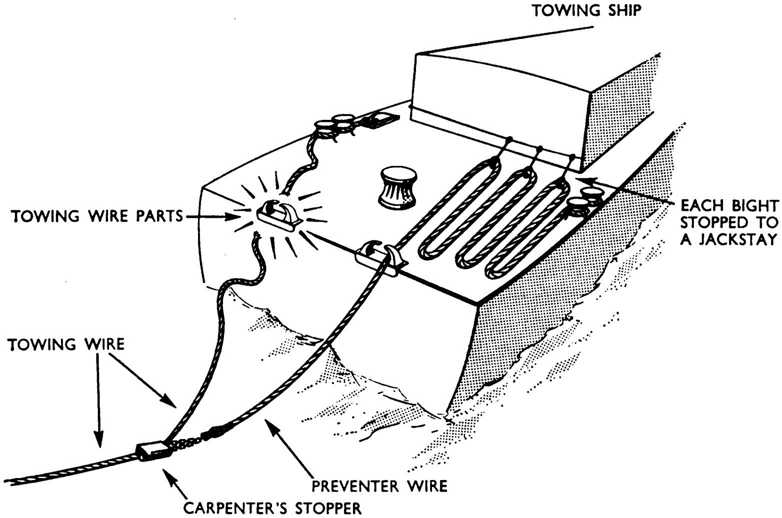


FIG. 6–9. Use of a preventer wire to hold and recover the tow if it parts

Speed of tow

A fair assessment of the maximum safe towing speed in calm water can be made from the graphs at the end of this chapter. In these conditions, and provided the tow is handling well, there is no objection to towing near the maximum speed that allows a reasonable safety margin for the gear in use. But at the first sign of deteriorating weather one must reduce speed drastically so as to anticipate the increased stresses.

In a long ocean tow the expected weather is usually the factor that dictates the speed. The average rate of progress on a long-distance tow may be as little as four knots, and at such low speeds the effects of wind and currents are proportionately very large. Wind charts, current atlases and weather forecasts should be carefully studied, and the track of the ships should be planned to take advantage of favourable winds and currents and to avoid adverse ones. When towing, the shortest route is not always the quickest.

YAWING OF THE TOWED SHIP

Most vessels when in tow have a tendency to yaw to one or both sides of the course, but if the yaw is not excessive and the towed ship is able to steer, no difficulty should be experienced. If the towed ship is unable to steer and the yaw is excessive the towrope will be subjected to heavy stresses, particularly at the limit of each yaw, and it may also be severely chafed or nipped. The following

factors, singly or in combination, may make a ship yaw or contribute towards her tendency to yaw:

the direction and force of wind and sea relative to her course,
her freeboard, draught, and the disposition of her superstructure,
her trim,
any list she may have on her,
any underwater projections caused by damage to her hull.

The more deeply laden a ship the less tendency will she have to yaw, and of the yawing factors trim has the greatest effect.

Effect of wind and sea

With an undamaged ship in normal trim little can be done to correct yawing caused by wind and sea except by altering course or altering the speed of towing. A ship with a high forecastle and superstructure forward, such as a destroyer or frigate, will tend to bore up to windward, and a ship with her superstructure aft, such as a tanker, will tend to pay off to leeward. In a cross-wind the frigate will probably first fall off to leeward and then bore up into the wind, and so yaw from one side of the course to the other, whereas the tanker will probably pay off to leeward and then ride there at a steady angle of sheer. In a following wind and sea the tanker, particularly one with a counter stern, will tend to yaw more than a frigate; but in a head wind there should be little tendency for either type of ship to yaw.

Effects of trim, list and underwater projections

The more a ship is trimmed by the stern the steadier will she be when in tow; and conversely, the more she is trimmed by the head the greater will be her tendency to yaw. In fact a ship trimmed well down by the head will be unmanageable if towed bows first, and she should therefore be towed stern first.

A ship with a list will tend to sheer off towards her high side, and this tendency will be increased by a cross-wind blowing on that side. But a cross-wind blowing on her low side will tend to steady her.

Underwater projections caused by damage to the hull structure will have an effect similar to that of trim or list. If the projections are before the ship's pivoting point the effect will be the same as if she were trimmed by the head, and *vice versa*, and if they are to one side of her centre line she will tend to sheer towards that side.

Correction of yaw

Yawing may be corrected or reduced in a number of ways, and the choice of method must depend upon its cause and the circumstances of the tow.

The chief cause of yawing is usually that the ship is not trimmed sufficiently by the stern. Trim is best corrected by transferring liquids or ballast from one part of the ship to another, because then her reserve of buoyancy is maintained. If trim is corrected by flooding or by adding ballast, it should be done with discretion, otherwise the ship's stability, reserve of buoyancy, or seaworthiness may be dangerously affected.

If altering the trim of the ship is impracticable, or if her yawing is not due to incorrect trim, one or other of the methods described below should be tried. These have all proved successful in practice, but most of them increase the drag of the towed ship, and may subject the towrope to exceptional stresses or to a bad nip or chafe. Increasing the drag may reduce the speed of towing below what is economical or efficient.

Altering the speed. Yawing may be increased or reduced by altering the speed of towing. Yawing caused by list is usually decreased by increasing the speed of towing, and yawing caused by trim is usually decreased by reducing the speed of towing.

Setting the rudder. If a ship's steering gear is damaged her rudder may still be workable by hand, either by gearing or by reeving tackles on the tiller. By setting her rudder at an angle the towed ship may be steadied at a constant angle of sheer to one side or the other of the towing ship's track, but it may then be necessary to alter the lead of the towrope to ensure that it is not subjected to a bad nip or chafe. If the rudder angle or the angle of sheer is large this method may be impracticable because of the increased drag of the towed ship.

Towing another ship astern. Securing a second rescue ship with a hawser astern of the disabled ship, and using this rescue ship as a kind of powered rudder, has been tried with success on a number of occasions. The second ship is secured by her bows to the stern of the disabled ship, and may need to veer some cable on the end of her towrope. She then keeps a slight stress on her towrope and sheers to one side or the other as necessary to keep the disabled ship on course. Smartness in obeying engine orders is a paramount necessity in the astern-towing ship.

On one occasion a ship which had lost her rudder, but which was otherwise undamaged, used another ship as a rudder by taking her in tow, and was able to proceed in a high wind and sea on a fairly steady course without any other assistance.

Shifting the point of tow. A ship which is yawing to one side of the course may be steadied at a constant angle of sheer by shifting the point of tow further aft on the inner bow. But this is only practicable if the resultant angle of sheer is not too great, and if the towrope is not subjected to chafe.

Setting a sail. Setting a sail in the towed ship either right forward or right aft may reduce the yaw. A boat's sail or a small awning can be used with an improvised rig.

Towing a drogue. Towing a drogue astern may steady the towed ship, particularly if she is a fairly small one with fine lines. Drogues that have proved successful have included a bight of 6-inch manila hawser; one or two shackles of the ship's cable streamed on a messenger; a provision net, filled with shot mats, towed on a two-legged bridle; and a multiplane kite otter, as used for minesweeping.

Propellers. Although as a rule the propellers of the towed ship should be allowed to trail, it may be that one or more of them, if stopped, will drag in such a way as to reduce the yaw.

SHORTENING-IN THE TOW

Before entering shallow or restricted waters, or handing over to harbour tugs, the tow must be brought to short stay. This will give better manœuvrability. It will also ensure that the bight is kept clear of the bottom, which is essential if the bottom is rocky or uneven. When the towing ship has a powerful winch aft, shortening-in can be carried out while still retaining headway, though speed should be reduced as far as possible to relieve the strain. Similarly the disabled ship, if she has power, will have no difficulty in retrieving her cable. When neither ship can heave in by power, the towing ship must ease down gradually until both ships are stopped, and then endeavour to haul in the towing hawser by hand. But this procedure will only be practicable if plenty of sea room is available and, in shallow water, if the bottom is free of snags. If shortening-in by hand proves impossible it may be necessary to slip the sea tow at both ends as soon as the disabled ship has been taken over by the harbour tugs.

When towing in restricted waters, make ample allowance for the drift of the tow to leeward and for leeway, in order to keep the towed ship clear of navigational marks and dangers.

EMERGENCY ACTION WHEN TOWING

Slipping and buoying the towrope

The after towing arrangements of a warship incorporate a slip to enable her to slip the towrope in emergency and so regain her freedom of manœuvre. If the towrope is slipped it will be difficult, and sometimes impossible, for the towed ship to recover it, and when towing is resumed time will be wasted in recovering the towrope or passing a new one. If in sufficiently shallow water the towing ship should therefore buoy the end of the towrope before slipping it, the buoy being rigged with a stave and flag. A good method is to reeve the buoy-rope as a double whip through a block shackled to the end of the towrope, the buoy-rope being strong enough for weighing the end of the towrope.

Encountering heavy weather

In very bad weather it is probably preferable to turn and run slowly before wind and sea. Heaving-to head to sea is likely to result in far heavier strains on the gear, although steering may be easier. When running with the gale it may be possible to steady the disabled ship by streaming a drogue. Obviously one cannot run if this is likely to bring the ships near a lee shore.

In extreme weather conditions which the gear cannot be expected to withstand, it may be preferable to slip the tow rather than to hold on until the gear parts. The disabled ship may ride more easily when drifting, with the towing gear trailing as a sea anchor, while the towing ship will have freedom of manœuvre and can spread oil where it will be most effective.

Recovery of the entire tow, when the weather moderates, will probably be impracticable unless the disabled ship can use her windlass, or unless the water was shallow enough for the end to be buoyed when slipped.

Use of oil in rough weather

Heavy seas breaking on board may often be dangerous, especially if the ship is disabled. Even in the roughest weather, however, seas can be prevented from breaking by spreading a small quantity of oil on the surface of the water, a rate of only a few gallons an hour being sufficient. The best oils to use are those of fish, animal or vegetable origin, and the next best are ordinary boiler fuel and diesel oil. In cold weather the oil should be heated to decrease its viscosity. The oil can be distributed in many ways, some of which are described below.

1. Fill a one- or two-gallon tin with oil, punch sufficient holes in its bottom to give the required rate of flow, and place it in a water-closet pan, wash-basin or bath, so that the oil runs or is flushed outboard through the soil-pipes.
2. Take an old wash-deck hose, cut off the connections, sew up one end and prick a number of holes along its length with a sailmaker's needle. Then fill the hose with oil, close its other end with a strong seizing, and stop the hose to the gunwale at the required position.
3. Take a bag, fit it with a two-legged sling, ballast it with a weight of about 7 pounds and pack it, not too tightly, with cotton-waste or oakum. Then with a sailmaker's needle prick a number of holes in the bottom and lower half of the sides of the bag, fill it with oil, close its neck with a strong seizing, and trail it in the water on a line.

Both ships should distribute oil, the positions from which to distribute it depending upon the direction of the wind and sea. If wind and sea are from abaft the quarter, oil should be distributed from each bow and quarter and from amidships on each side. If wind and sea are from between the quarter and the bow, oil should be distributed on the weather side from the bow, from amidships and from the quarter. If wind and sea are from before the bow, oil should be distributed from each bow. If wind and sea are before the beam and the towed ship is yawing badly, the towing ship should sling the bag described above by a bow-shackle on the towing hawser, tail it with a strong messenger, and allow it to slide well down the hawser so that it will distribute the oil ahead of the towed ship within the limits of her yaw.

If oil is used when taking a vessel in tow, the lines and hawsers should, if possible, be kept clear of the oil, otherwise they will become slippery and very difficult to handle.

Beaching a damaged ship

If the towed ship appears to be sinking it may be possible to beach her in time to save the ship. The optimum conditions for beaching are a sheltered bay, a soft and gently shelving bottom, and high water. If the value of the sinking ship warrants the risk, secure the towing ship alongside the lee quarter of the other and push her as far in towards the selected beaching point as practicable before slipping and going astern to clear her. Before attempting the operation the towing gear must be recovered, in order to prevent the disabled ship from anchoring herself before reaching the beach.

When the decision is taken to beach, there may be other ships standing by which are more suitable for the purpose because of their lighter draught or

better manœuvrability. The best control during a beaching will be achieved by securing a light-draught ship on each quarter of the disabled vessel. When the towing ship is of greater draught, or if for other reasons the risk of securing alongside the sinking ship is not justified, the best that can be done is to heave in the tow to short stay and cut adrift when heading in the general direction of the beach, while there is still room to manœuvre clear. Some remarks on the stability of a grounded ship will be found in Chapter 1.

Taking an anchored ship in tow

If there is little sea, the simplest method of passing a tow to an anchored ship will probably be from alongside her, and on the opposite side to her cable if she has only one anchor down. When the tow has been passed, the towing ship should move ahead and stand off well clear while the anchor is being weighed, keeping the towing hawser fairly taut and off the bottom. It is more likely that this operation will be required in emergency to keep the anchored ship—which, it is assumed, has no power on her main engines—from drifting on to a lee shore in a gale. A man-of-war attempting this feat, particularly in confined waters, will be severely handicapped as compared with a salvage tug.

Should she approach downwind and pass the tow from her forecastle, the towing ship will then find it very difficult to steer astern. Most warships have astern power that is very inferior to ahead power, and many cannot keep up astern revolutions for long periods.

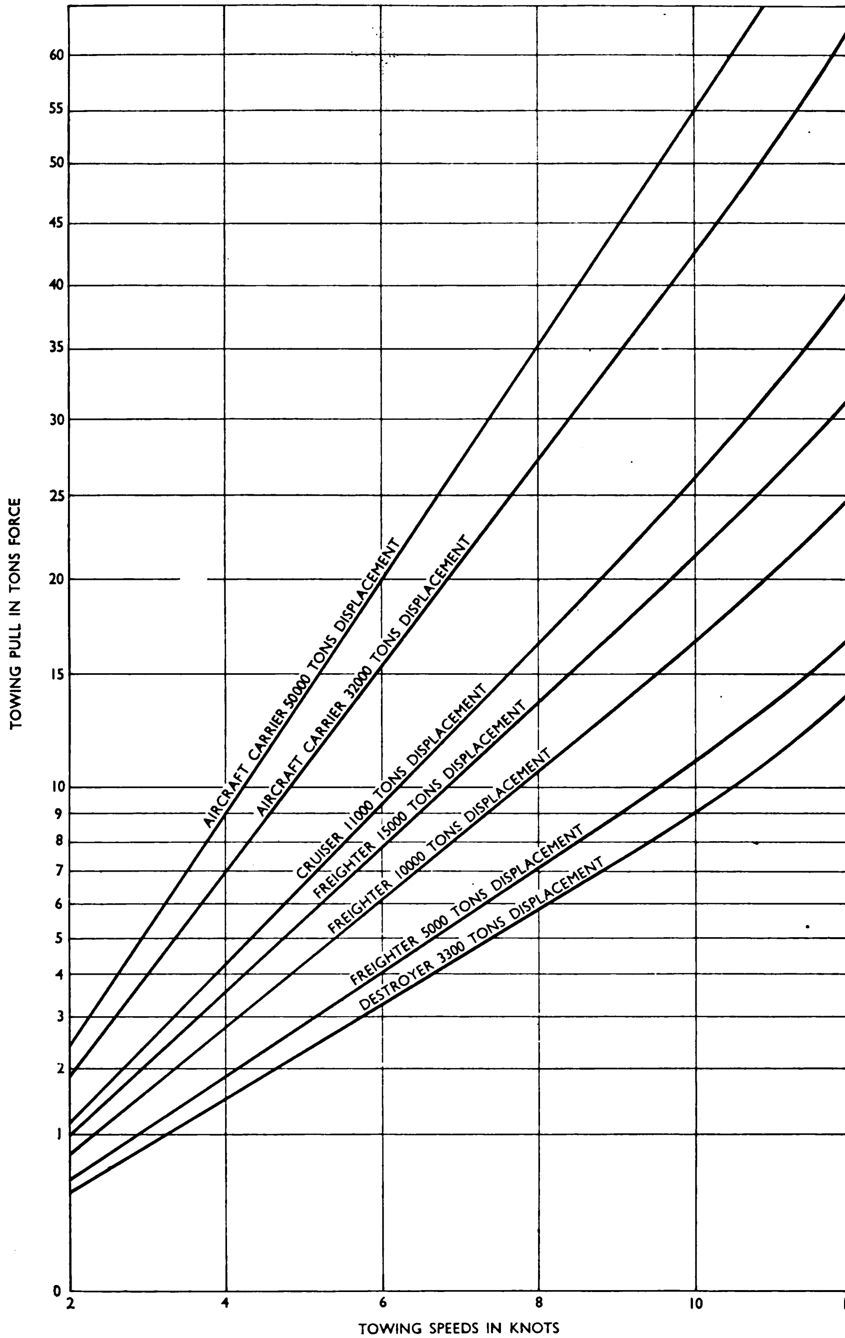
If she approaches head to wind and passes the tow from aft, she will then find it impossible to keep head to wind and will pay off rapidly to one side or the other, possibly colliding with the anchored ship.

The only method that appears to have a chance of success is to anchor the towing ship to windward of the disabled ship in such a way that, after veering a good scope on her cable, her stern is within line-throwing distance of the disabled ship. The tow is then passed and the towing ship takes the strain by using her engines and at the same time shortening-in the cable. When the time comes, the disabled ship either weighs or slips her cable and the towing ship goes ahead.

TOWROPES

Composition

In H.M. ships wire rope is used for towing because it is neither so bulky nor so heavy as cordage of similar strength, and is therefore more easily stowed and handled. It possesses very little elasticity, however, and will part if suddenly subjected to a load which, if applied gradually, it would have withstood with ease. Towropes are therefore often of a composite nature to provide them with the required degree of elasticity or springiness. Elasticity can be provided by incorporating a length of cable-laid manila of approximately the same strength as the wire rope; and springiness can be provided by incorporating a length of chain cable which, though inelastic, by reason of its weight acts as a spring and so is able to absorb the energy caused by a sudden load. Nylon is being used increasingly as a material for towropes, because it has much greater elasticity than wire and does not require any cable to be incorporated in the tow to give springiness.



NOTE:

(1) THESE CURVES ARE FOR CALM WEATHER AND FOR SHIPS 3 MONTHS OUT OF DOCK. TO ALLOW FOR FOULED BOTTOMS, BAD WEATHER OR YAWING, INCREASE THE FACTOR OF SAFETY.

(2) THE TONNAGE SHOWN AGAINST FREIGHTERS IS THEIR DISPLACEMENT TONNAGE AT DEEP LOAD DRAUGHT AND NOT THEIR GROSS TONNAGE.

FIG. 6–10. Type of ship, towing pull and towing speed

For ocean towing by tugs not provided with self-tensioning winches the tow rope is usually composed of manila rope, wire rope and chain cable; but for emergency tows it is quickest and simplest to use a wire hawser shackled to a suitable length of the towed ship's anchor cable. For emergency tows at short stay, such as towing a burning vessel clear of shipping in harbour, the hurricane or spring hawser described in Volume I probably makes the most efficient towrope.

Admiralty ocean-going tugs are fitted with automatic self-tensioning towing winches that allow the towing wire to render or heave according to the strain experienced. These tugs therefore do not need to use cable-laid manila or chain cable in the composition of their towropes. In addition, they are supplied with Nylon hawsers in lengths up to 100 fathoms and sizes varying from 5-inch to 10-inch. The properties of Nylon hawsers are described in Volume I. So far as towing is concerned, the great elasticity of Nylon obviates the need for a deep bight in the towrope.

Strength

The required strength of a towrope depends upon the power available in the towing ship, the intended speed of towing, and the displacement of the towed ship. A rough rule for estimating the towing power of a tug fitted with reciprocating engines is to allow a pull of one ton for every 100 units of indicated horse-power; thus a vessel of 2,000 I.H.P. can be expected to exert a maximum pull of about 20 tons in good weather. For diesel-driven tugs the pull is somewhat higher and in some cases may be as much as 1·6 tons per 100 units of S.H.P. The forces required to tow various types of warships and freighters in calm weather at various speeds can be found from the graph in fig. 6–10. These forces will be greatly increased in rough weather, in a heavy swell, when the towed ship yaws badly or is damaged, or if the ships' bottoms are heavily fouled; a 60 m.p.h. gale, for example, would increase by some 25 tons the pull required to tow a cruiser. It is emphasised that the tonnage shown in the graph against the freighters is displacement tonnage at deep-load draught, and not gross tonnage. It will be noticed that a lesser towing pull is required for freighters than for cruisers of similar displacement. This difference is caused by propeller drag, a cruiser having usually four large-bladed propellers, whereas a freighter usually has one, or at the most two, small bladed propellers.

Selection

The choice of towrope depends upon the pull required and the factor of safety it is intended to use. The factor of safety in turn depends upon the gear available and such circumstances as the duration of the tow, the weather, and the urgency of the situation; but it is recommended that it should be not less than four. The graphs in figs. 6–11 and 6–12 show, respectively, the size of F.S.W. rope and E.S.F.S.W. rope which are required for various pulling forces using various factors of safety. Fig. 6–13 gives the corresponding data for 3-strand hawser-laid Nylon rope. With these graphs and the graph in fig. 6–10, the seaman who has at his disposal unlimited towing power and choice of gear can select the type and size of towrope to suit his particular requirements; and, conversely, the seaman with limited resources can estimate the safe capabilities of the gear available.

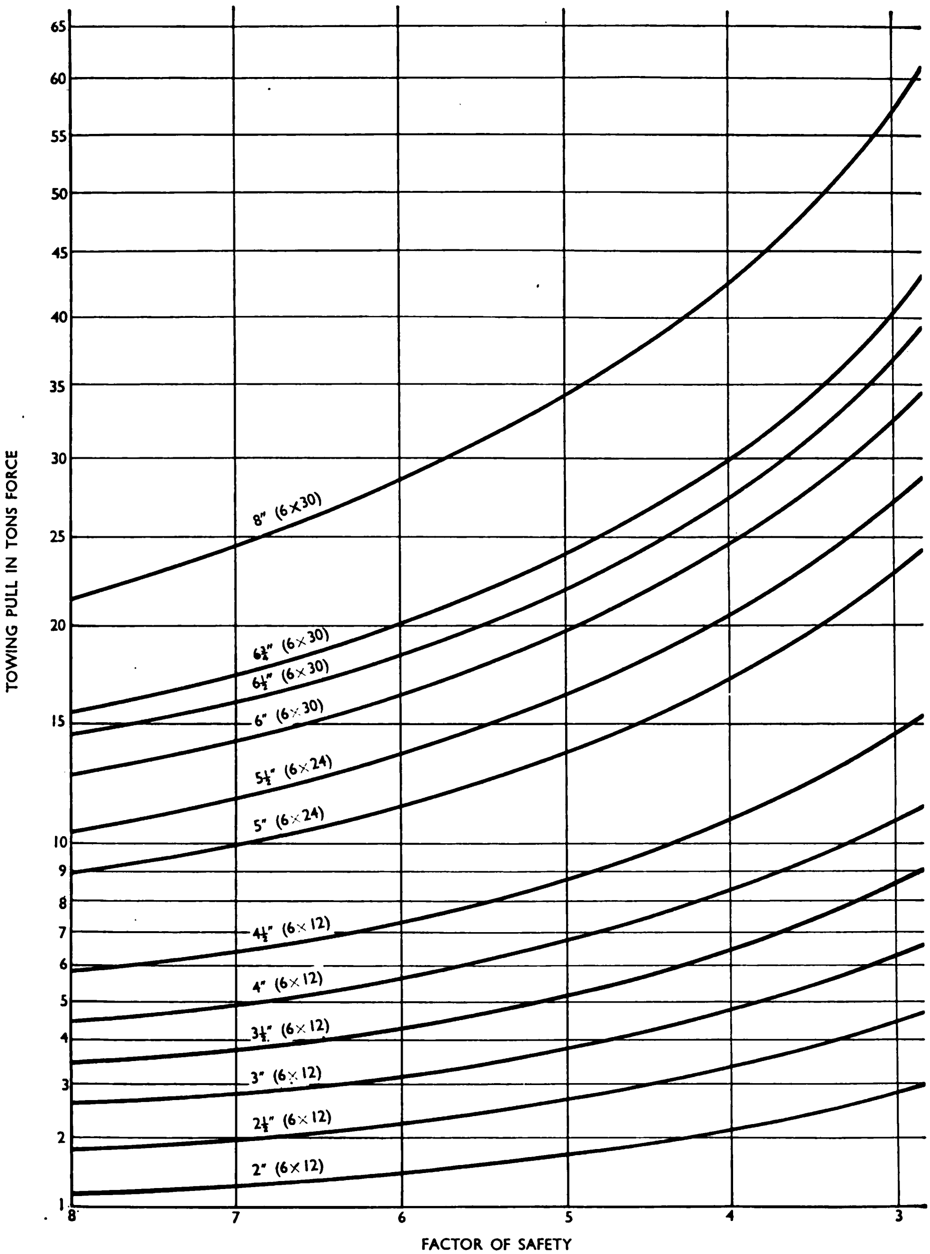


FIG. 6–11. Towing pull and factor of safety for F.S.W. rope

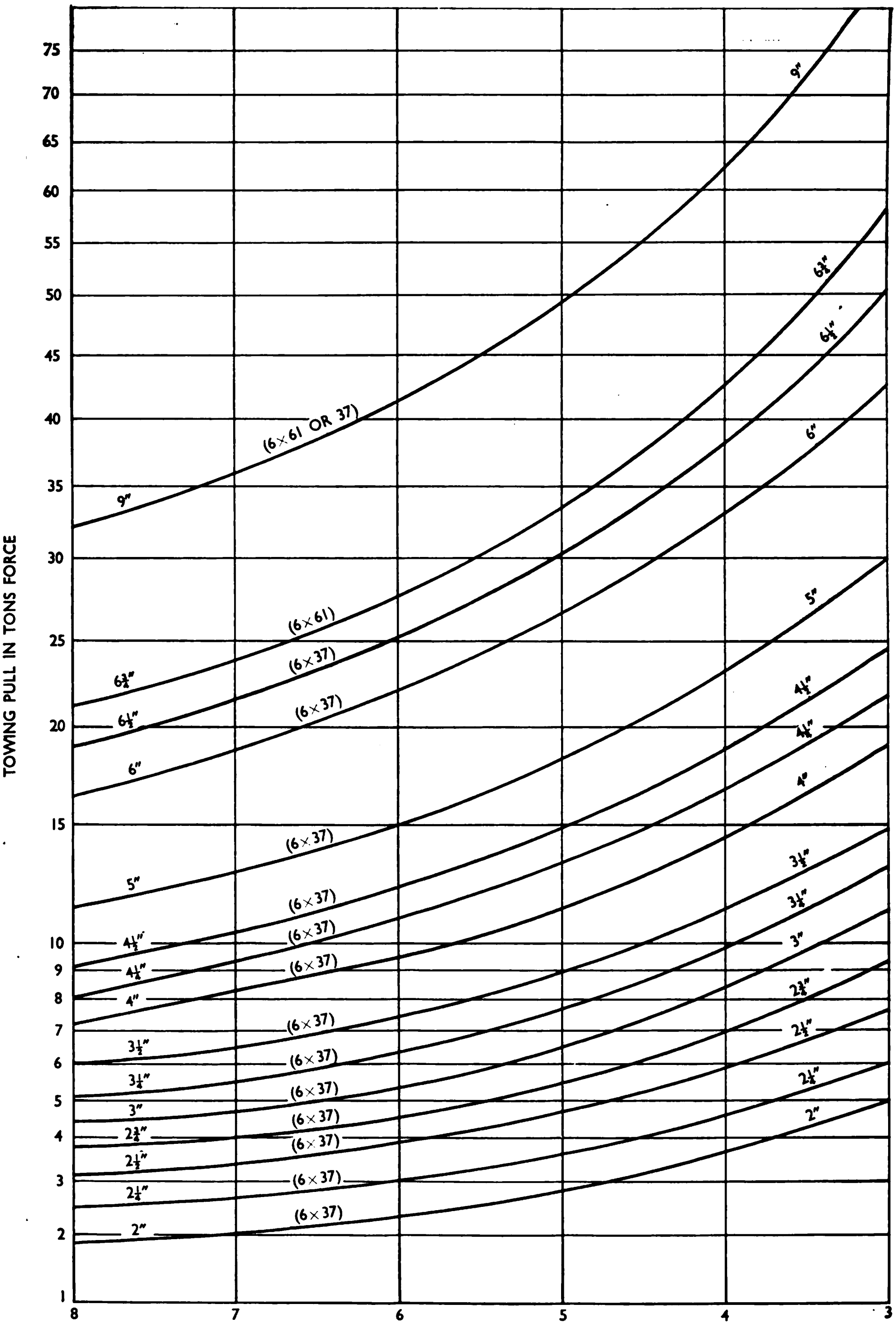


FIG. 6–12. Towing pull and factor of safety for E.S.F.S.W. rope

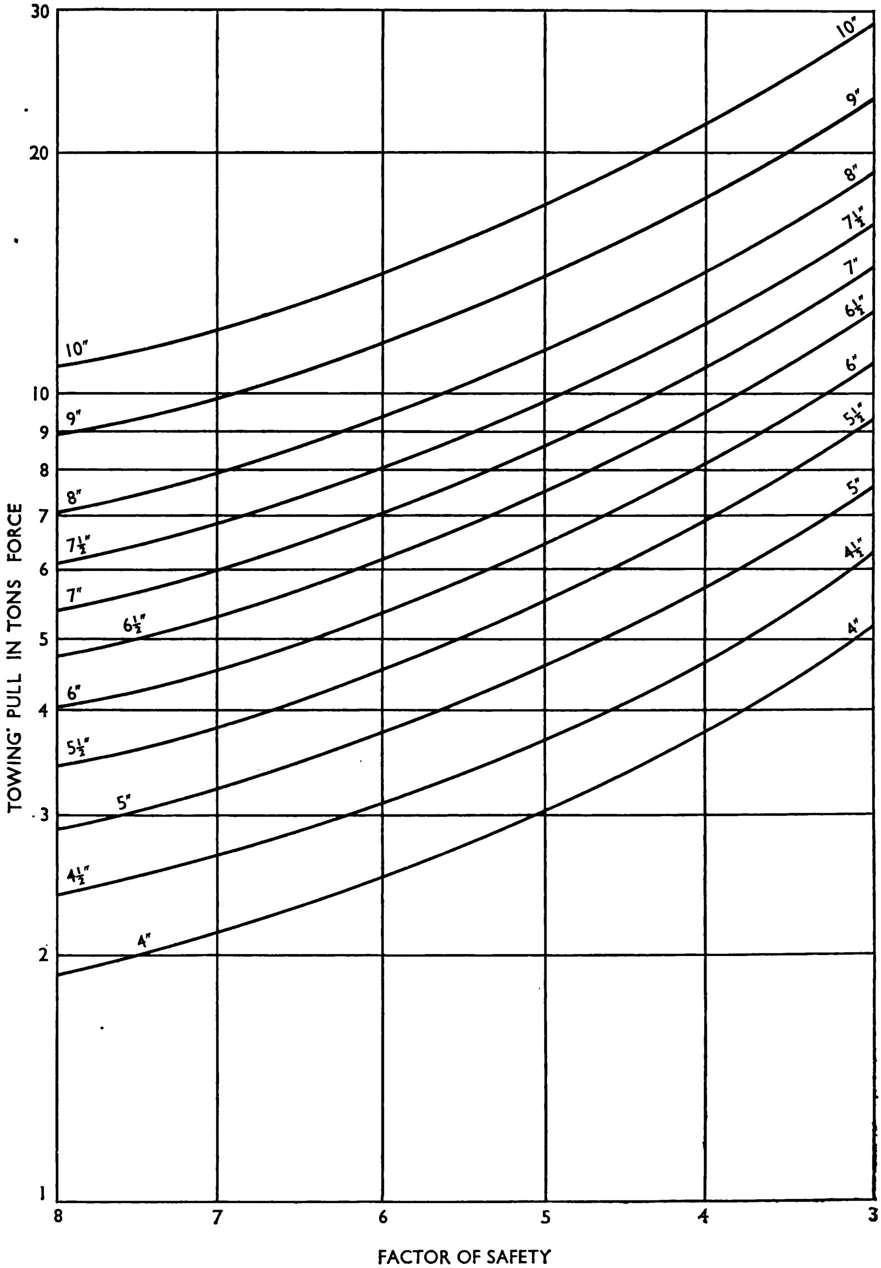


FIG. 6–13. Towing pull and factor of safety for 3-strand hawser-laid Nylon rope

Length

The length of towrope to be used depends upon the sea room available, the depth of water, the displacement of the towed ship, the required speed of towing, the factor of safety used, the weight of the towrope, and the weather. The chief requirement in towing (except when using Nylon) is to ensure that when the ships are moving at the required speed there is a sufficient sag in the bight of the towrope to absorb any sudden fluctuating loads. The amount of this sag depends upon the pulling force exerted and the length and weight of the towrope, and the lighter the towrope the longer it must be. The sag must not be too great, because not only may the bight then foul the bottom, but the towing ship will have to exert an additional pulling force to drag the bight through the water and also support its weight. For this reason, and because the ships are then more manœuvrable, a short, heavy towrope is preferable to a long, light one.

The graph shown in fig. 6–14 gives the length of wire hawser necessary in calm weather to obtain a required depth of sag in the bight. Having determined this depth and the factor of safety, and having selected the type of hawser for the job, the appropriate curve in the graph is taken and the required length of towrope is read off the scale along the bottom.

The graph shows the length of towrope required if using F.S.W. or E.S.F.S.W. rope only; but because the usual practice is to use a composite towrope of chain cable and wire rope, the length shown by the graph can be reduced by an amount corresponding to the length of chain cable veered, and still maintain the bight of the towrope at the required degree of sag. The length by which the towrope can thus be shortened is given by the formula:

$$L = k\frac{c}{d}(H-h)$$

where:

L is the length of cable to be veered, in fathoms;
H is the length of towrope, in fathoms, shown by fig. 6–14;
h is the length, in fathoms, of hawser available or required;
c is the circumference of the hawser, in inches;
d is the diameter of the cable, in inches;
k is a constant which is 0·11 for F.S.W.R., and 0·13 for E.S.F.S.W.R.

In rough weather a deeper bight is necessary to absorb the sudden loads to which the towrope will be subjected, and this is better obtained by veering cable than by veering the hawser. The amount of cable to be veered can be obtained from the graph and by using the above formula. It is recommended that the bight of the towrope should be immersed to a depth of at least 4 fathoms in calm weather and at least 6 fathoms in rough weather.

How to use the graphs

The following examples show how the graphs are used to determine the length and composition of the towrope for a particular towing problem, and the probable safe speeds of towing.

It is required to tow a deeply-laden freighter of about 5,000 tons deep-displacement, for which the freighter's anchor cable of 2-in. wrought iron and a 150-fathom 4-in. F.S.W. hawser are available. What should be the length and

composition of the towrope, and what will be the maximum speed of towing in calm weather?

From fig. 6–11 it is found that a 4-in. F.S.W. hawser can take a towing pull of 8½ tons using a factor of safety of four, or a towing pull of 6¾ tons using a factor of safety of five, or a towing pull of 5¾ tons using a factor of safety of six.

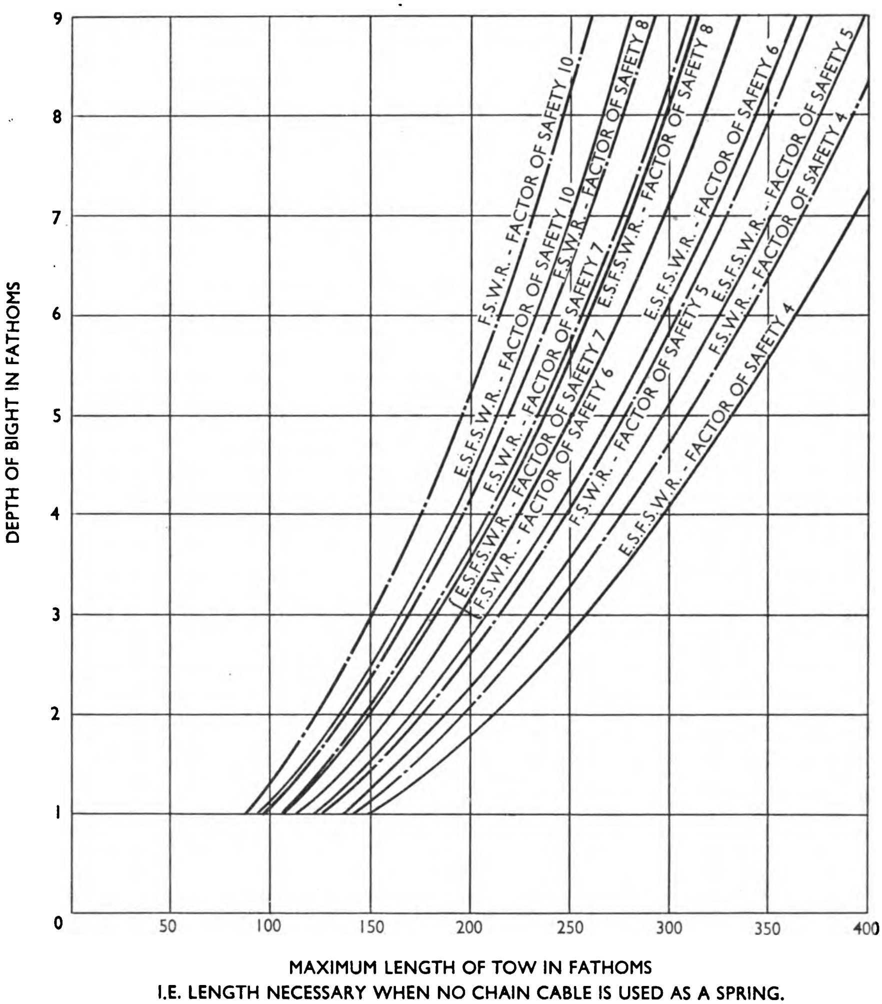


FIG. 6–14. Dip of towrope in relation to length of tow at known factors of safety

The factor of safety used and the speed of towing will depend upon the urgency of the situation, the probable duration of the tow, and the weather. Assuming that the situation is urgent, that the freighter must be towed at the maximum practicable speed for about 30 miles, that the sea is calm and that the weather forecast is good, it would be reasonable to use a factor of safety as low as four. From fig. 6–10 it is found that a towing pull of 8½ tons will give a towing speed of about 8½ knots.

The lower the factor of safety used the longer must be the towrope to ensure a good depth of bight. As the sea is calm it would be reasonable to allow for the bight of the towrope to be submerged to a depth of 4 fathoms, to which must be added the mean height above water level of the ends of the towrope, say $2\frac{1}{2}$ fathoms. From fig. 6–14 it is found that with a depth of sag of $6\frac{1}{2}$ fathoms and a factor of safety of four for F.S.W.R. the length of wire hawser required would be 350 fathoms. This length can, however, be reduced to 150 fathoms (the length of hawser available) if three shackles (45 fathoms) of the freighter's anchor cable are used as part of the towrope. (See formula on page 136.)

Reducing the speed of towing will increase the factor of safety and increase the depth of sag in the bight of the towrope. If the ships are in shallow water, or if they have to pass over a shoal patch, there may be a danger of the towrope fouling the bottom and parting. To avoid this the towrope must be shortened, and the graphs and the formula can be used to determine the length and composition of towrope required to maintain the reduced depth of sag and factor of safety at the new speed of towing.

If, for example, the speed of towing is reduced to 6 knots, reference to fig. 6–10 shows that the corresponding towing pull is reduced to 4 tons. On referring to fig. 6–11 it is seen that with this reduced towing pull the factor of safety for a 4-in. hawser is increased to over eight. By referring to fig. 6–14 it is seen that with a factor of safety of eight a 250-fathom length of hawser is required to maintain a sag in the bight of $6\frac{1}{2}$ fathoms, and that this length can be reduced to 100 fathoms by using 35 fathoms of the freighter's cable. In practice, however, it may be simpler to adjust the length of tow by heaving in or veering the cable in the towed ship than by heaving in or veering the hawser in the towing ship, and in this example the same effect is achieved if the freighter heaves in 23 fathoms of cable, thus making a towrope comprising a 150-fathom length of 4-in. hawser and 22 fathoms of cable, this being equivalent to a towrope comprising 100 fathoms of hawser and 35 fathoms of cable.

Summary

The chief requirements for towropes (other than Nylon) may be summarised as follows:

1. The towrope should be long enough and heavy enough for a large part of the bight to be immersed when towing at the required speed.
2. When determining the proportion of cable to hawser in a composite towrope, remember that the larger the proportion of cable the better will be its spring.
3. Remember, also, that the larger the proportion of cable the shorter will be the required length of towrope, and the shorter the length of towrope the more manœuvrable will be the ships.
4. The rough rule for determining the proportions of cable and hawser used to provide a towrope of a certain weight is that cable, if steel, is about five (or if wrought iron, about seven) times as heavy as wire rope of approximately the same strength.
5. A good rough rule for towing in moderate weather is: Use three shackles (45 fathoms) of the towed ship's anchor cable shackled to 150 fathoms of wire hawser of a size of about two-and-a-half times the size of the cable. With a 2-in. cable, for example, use a 5-in. hawser.

CHAPTER 7

Salvage Operations

The salvage of a ship, particularly one which is sunk, or stranded and severely damaged, is usually a complicated operation only to be carried out by specialist salvage officers and with special equipment. Some salvage operations are, however, well within the capabilities of a resourceful seaman using the normal equipment of a well-found ship or the equipment obtainable at any port. The purpose of this chapter, therefore, is to provide the seaman with an elementary knowledge of the methods and requirements of ship salvage, and so enable him to undertake its simpler forms, or in complicated cases to take such emergency measures as will simplify subsequent salvage operations by experts or even prevent the total loss of the ship.

SOME LEGAL ASPECTS OF SALVAGE

It is, of course, the duty of every seaman to afford every possible aid to vessels in danger, in distress, or in want of assistance, and to save life. When property, such as the ship or her cargo, is also saved the salvor or his employer is usually entitled to claim recompense in the form of a salvage award commensurate with the degree of assistance rendered and the value of the property saved.

If the vessel is in immediate danger or dire distress any such aid will obviously be welcomed by her master and crew and accepted without demur; but if the vessel has not been abandoned and if she or her crew are not in immediate danger it is usual for her master or owner to come to some form of agreement with the prospective salvor in regard to the degree of assistance required. When offering his services the prospective salvor should bear in mind that salvage awards are made only when the services rendered are successful or have materially assisted in the saving of property, and that no claim can be entertained if the efforts are unsuccessful; moreover, wrongful methods of salvage resulting in further damage or loss of property, or even the loss of the ship, may render the salvor liable in respect of such damage or loss.

It is therefore very important that full agreement on methods to be adopted should be reached between the salvor and the master or owner of the vessel, but it should be remembered that the master is at all times responsible for his ship and her cargo, and that a salvor has no right to give him orders. At the same time it may be presumed that if the master has asked for assistance he is willing to accept advice and to co-operate.

Instructions to naval officers about offering salvage assistance, and the procedure in claiming salvage awards for such services, are laid down in *Q.R. & A.I.*, and the following remarks amplify them.

Before starting operations the prospective salvor should, if possible, board the vessel and consult with her master, who should be requested to sign *Lloyd's Standard Form of Salvage Agreement.* If this is impracticable the salvor should

try by every means to get the master to agree to sign the form later, as and when convenient. The agreement is usually accepted in its 'open form', that is to say the remuneration payable in the event of salvage being successful is open to arbitration, and the basis of agreement is 'no cure, no pay'. In the case of a vessel abandoned by her crew this matter does not arise.

Any reports rendered during salvage operations should be carefully worded, because many interests are concerned in marine casualties, and the insurance markets react strongly to such reports as may be published. Whoever is in charge of salvage operations should therefore confine himself strictly to details of damage and to the existing situation, and he should avoid any predictions.

EMERGENCY AID TO VESSELS AFLOAT

A vessel at sea which is so damaged that she requires assistance will probably require to be towed to port, but before taking her in tow the extent of her damage should be examined and its effect on her seaworthiness should be considered. If the damage is considerable and the nearest port with good repair facilities is some distance away it is preferable to tow the vessel to the nearest safe anchorage as quickly as possible and there make temporary repairs before attempting the long passage. This may seem obvious, but ships have in fact been lost because this elementary precaution has been neglected.

If the vessel is leaking badly she should be beached, because her seaworthiness will rapidly deteriorate as she loses her buoyancy. Also, the deeper a ship sinks in the water the greater will be the water pressure on the leaks and exposed bulkheads, and should the latter collapse the vessel will probably sink. Remarks on the stability of a grounded ship are to be found in Chapter 1.

Firefighting

It may be necessary to get fires in the damaged ship under control before any attempt at salvage can be made. Methods and Royal Navy equipment for fire-fighting are described in the relevant chapters in Volumes I and II, while typical firefighting arrangements in merchant ships are outlined in Chapter 5 of this volume. The firefighting equipment of Admiralty salvage vessels is listed on page 167.

Pumps and the confinement of flooding

During preparations for towing, all available portable pumps should be transferred to the vessel, even if their immediate need is not apparent; it is far better to have the pumps at hand and find eventually that they are not needed, than to have to stop towing for them to be transferred when an emergency arises. If the vessel has electric pumps and her electric generators are out of action, the practicability of providing her with electric power from the rescue ship should also be considered. A method of doing so is described on page 115. A quick general survey of the vessel should then be made, flooded compartments should be noted, and immediate steps taken to ascertain whether the leakage is likely to be within the available pumping capacity.

Generally speaking, it is advisable to concentrate on confining the flooding to as few compartments as possible, and where difficulty in pumping any badly

damaged space is anticipated it is best to concentrate on preventing any extension of the damage to surrounding spaces. The compartments to be dealt with first will therefore be those with the least leakage, because conditions will improve with every ton of water pumped out. These comparatively small leaks should be promptly dealt with so that the available pumps can be concentrated as soon as possible on the more extensively damaged sections, with the object of restoring the maximum amount of buoyancy.

Having ascertained the nature and extent of the damage, those compartments which are leaking should be inspected to see whether they can be tightened up and reclaimed. Continuous soundings should be taken in all compartments, even though they are remote from the damage, so that early warning of any increased leakage may be obtained. Pumps should be rigged with the shortest suctions possible so that they discharge overboard by the most direct route. It is always advisable to attach a stout line or a light purchase to the end of the suction-pipe so that it can easily be lifted and cleared if it gets choked. Any leaks which can be got at should be stopped with wooden wedges, plugs, tallow, etc., and all pumps should be concentrated on the badly damaged compartments as quickly as possible.

The amount of water, in cubic feet per second, which will enter a ship through any hole in her bottom can be estimated from the formula:

$$0{\cdot}62\, a\sqrt{2gH}$$

where:
a is the area of the hole in sq. ft;
g is 32·2;
H is the depth of the hole below the surface.

Two rough examples will give a practical idea of the application of this formula. A hole of 12 in. diameter 20 ft below the surface would allow an intake of 1,800 tons of water per hour, while a hole of 6 in. in diameter at the same level would allow an intake of 450 tons of water per hour. For a summary of the pumps available in different types of H.M. ships, see Chapter 2.

Emergency stopping of leaks

It is often impossible to get at leaks in the holds of a merchant ship because of the cargo there, and temporary measures have to be adopted to stem the inflow of water until more permanent repairs can be effected by divers at the nearest sheltered anchorage. To stop small leaks in seams or rivet-holes, bundles of oakum secured to a bottom-line with split-yarn and hauled under the ship and over the leak will often prove effective; the suction draws the oakum into the leaks and water pressure holds it there so long as the compartment is kept pumped out. For larger leaks blankets and mattresses backed by wooden battens dogged to bottom-lines and then hauled into place will often prove effective.

As soon as the vessel has been anchored or beached in a sheltered spot, these temporary measures should be replaced by more permanent repairs to make the vessel as seaworthy as possible.

Patching of leaks

The construction of large patches to cover extensive damage is usually beyond the resources of the seaman on the spot, but he should be able to make small

patches with the means at his disposal to cover less extensive damage. The construction and fitting of a simple wooden pad suitable for patching a small hole is described below and illustrated in figs. 7–1 to 7–5.

The materials to be used in the construction of patches depend largely upon what is available on the spot at the time. Tongued and grooved timber is most suitable, but not essential. A useful guide to the thickness of timber required to stand up to a given pressure can be obtained from the formula:

$$\text{thickness} = 3\sqrt{\frac{L \times \frac{1}{2}P \times 0{\cdot}015}{B}}$$

where:

L is the length, in feet, between the supporting surfaces on the hull structure;

P is the total pressure on the pad, in pounds per square inch; and

B is the breadth of the pad, in inches.

Having selected the timber necessary for the work the following additional materials will be required:

1. Two 3 in. $\times \frac{1}{4}$ in. flat steel bars, equal in length to the breadth of the patch,
2. Two 3 in. $\times$ 3 in. steel angle-bars of similar length,
3. Two angle-bars (to act as strongbacks) fitted with long draw-bolts,
4. Sufficient canvas to cover an area approximately 5 ft longer and wider than the patch,
5. A quantity of coir fibre for use as a pudding around the edges of the patch. (Oakum can be used instead of coir fibre, but is not so satisfactory as it has no spring when compressed.)

The canvas is first stretched out on the deck and the timber is then cut and laid centrally upon it so as to leave a 2 ft 6 in. margin of canvas all round, as shown in fig. 7–1. The two flat bars are then laid in position across the planks of timber, and holes are drilled through each bar and plank (two to a plank) and through the canvas backing so that the bars and planks can be firmly secured to each other by steel bolts.

If the pad is to be secured in place by draw-bolts the holes for these are now drilled through the bars, timber and canvas. The holes should be large enough to allow for the wood swelling under water, otherwise it will nip the bolts and make it impossible to adjust them when fitting the pad in its correct position.

The two 3 in. $\times$ 3 in. angle-bars are now drilled in a similar manner, using the flat steel bars as templates. The flat bars are then placed on the timber and the securing bolts driven through. Coir fibre is now teased out and laid so as to form a pudding-bolster nine inches in diameter around the edges of the patch, and the canvas is then turned over this and tacked down with flat-headed nails, as shown in fig. 7–2.

The pad is now turned over, canvas side uppermost, the two 3 in. $\times$ 3 in. angle-bars are fitted in place over the protruding bolt-ends, and the bolts are nutted and screwed home, thus completing the pad as shown in fig. 7–3.

The two strongbacks, cut to the required length, are now fitted with their respective draw-bolts. The hole for the draw-bolt should be drilled slightly

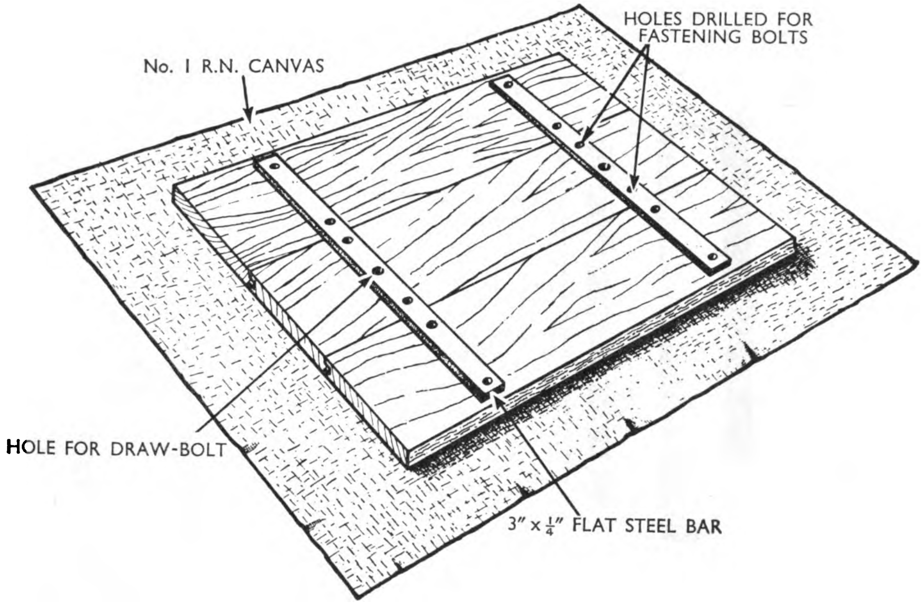


FIG. 7–1. Constructing a simple wooden pad for patching a small hole—first stage

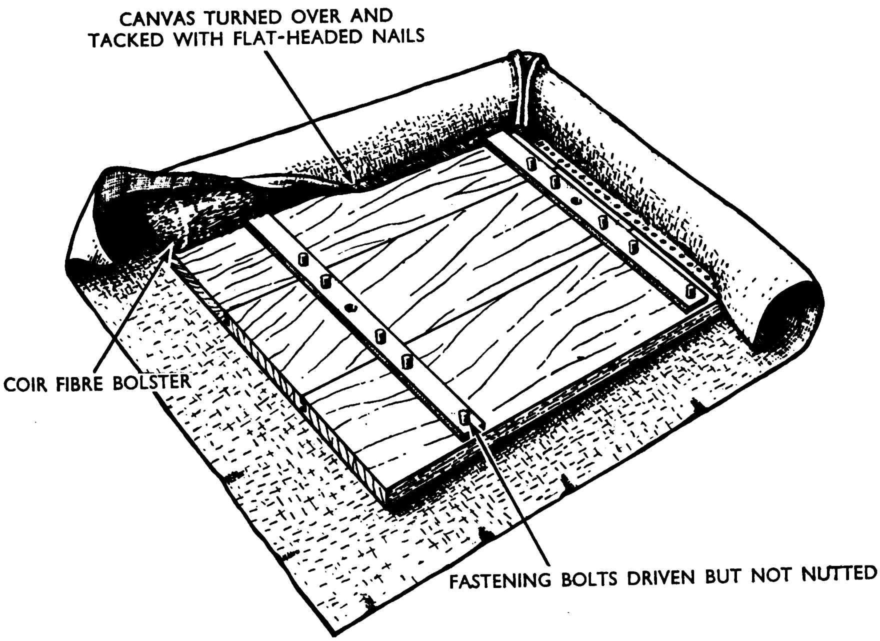


FIG. 7–2. Constructing a simple wooden pad for patching a small hole —second stage

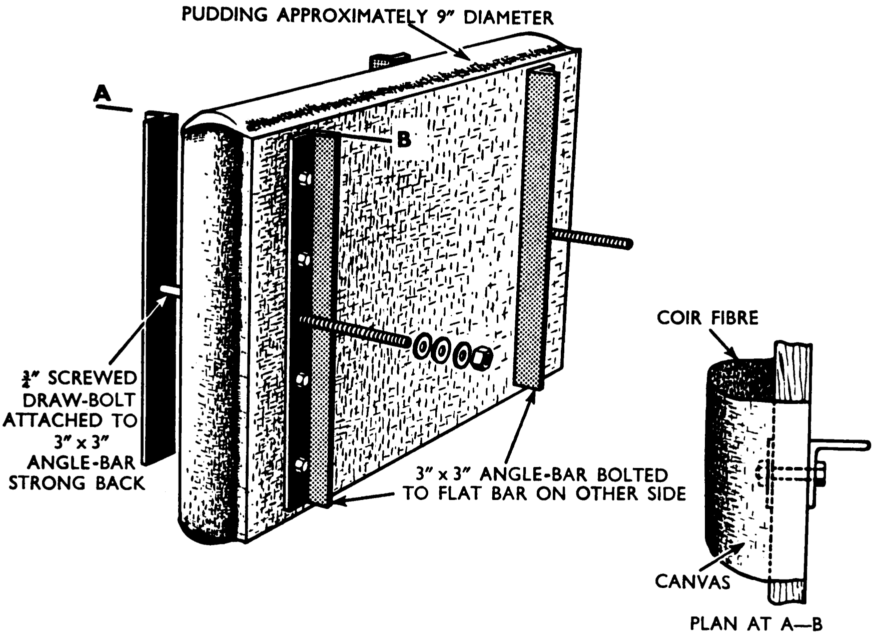


FIG. 7–3. Simple wooden pad—details of construction, showing draw-bolts

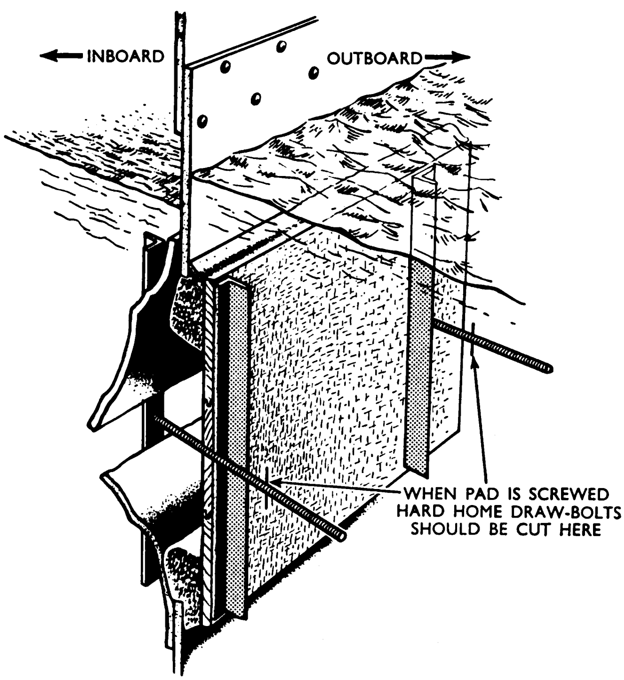


FIG. 7–4. Simple wooden pad, as fixed in position with draw-bolts

nearer to one end of the strongback than the other, so that the strongback will hang vertically when it is pivoted on the draw-bolt. Fig. 7–3 shows the pad complete with its draw-bolts and strongback, and fig. 7–4 shows the pad fixed in position.

A pad of this type, however, will probably float when placed in the water, and it must therefore be ballasted so that it can be slung over the side and lowered into position. The weight of ballast required is very simply calculated, as the following example shows:

Timber: 8 ft × 3 ft × $2\frac{1}{2}$ in.	= 5 cu. ft	= 180 lb
Pudding: 22 ft × 9 in. × 9 in.	= 9 cu. ft	= 12 lb
Angle-bars:		= 50 lb, say
Total volume and weight of pad	= 14 cu. ft	= 242 lb
Weight of water displaced by pad if entirely submerged	= 64 × 14	= 896 lb
Actual weight of pad		= 242 lb
Weight of ballast required		= 654 lb

Draw-bolts with angle-bar strongbacks provide the most efficient method of securing the pad in position when the hole is long and narrow, or where the plating is light and the frames widely spaced. But over a round hole, particularly one with its edges jagged and bent inboard, the pad will have to be secured in position with hook-bolts, as described below and illustrated in fig. 7–5.

To fit the pad with hook-bolts the outline of the hole is drawn on the canvas backing, and holes for the hook-bolts are drilled through the timber at suitable

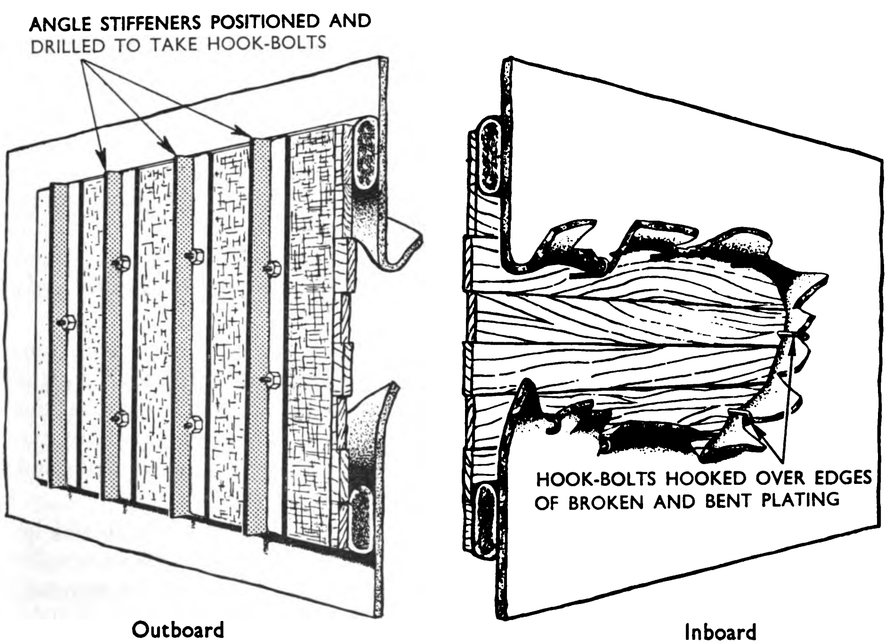


FIG. 7–5. Wooden pad for patching a hole, fitted with hook-bolts

intervals round, and well within, the indicated perimeter of the hole. The holes should be large enough to allow the hook-bolts considerable play so that when the pad is in position the hooked ends of the bolts can be placed as required. Such a pad will probably require stiffeners, which should be fitted to the outside of the pad and in such a manner that they are held in place by the hook-bolts.

Use of concrete

Mixture. Concrete, which is a composition of cement, gravel and sand mixed with water, is used extensively in salvage work for temporary repairs and leak-stopping, particularly where the work has to be done by divers and where there is no inflow of water through the leaks—in a submerged compartment, for example, which has been flooded up. It is also of particular value in repairing damage to the bilges of merchant ships where the frame-spaces between the margin-plates and the bottom-plating can be filled and there is no need to construct boxes to hold the concrete until it sets.

In salvage work *ciment fondu* is preferable to ordinary *Portland* cement because it sets more quickly and so will withstand water-pressure in a shorter time; good results can, however, be obtained with Portland cement, but the two should never be mixed. Cement by itself has very little strength, and so it must be mixed with coarse and fine *aggregate* in fixed proportions to make concrete. (Aggregate is a term used in the building trade to describe broken stones, gravel and sand; in this context coarse aggregate is gravel of $\frac{3}{8}$ in. to $\frac{3}{4}$ in. gauge and fine aggregate is sand.) For ordinary concrete work the proportions by volume are one of cement to two of fine aggregate and four of coarse; but for underwater work it is desirable to increase the proportion of cement used, and a good mixture for such purposes is one of cement to $1\frac{1}{2}$ each of fine and coarse aggregate by volume; this provides a quick-setting mixture which will give satisfactory results in a shorter time than that used for ordinary building purposes.

To make concrete the cement and aggregate are well mixed, and water is added until the mixture is of a consistency which can be easily worked into the corners and crevices of the space to be filled. In deciding on the quantities of materials required for a job it must be remembered that the volume of the mixture will be reduced by approximately 30 per cent when water is added during mixing. For quicker hardening, warm fresh water with a little soda added will help, but it is not essential.

When sending a mixture down to a diver one must prevent the cement from being washed out so that only sand and gravel remains when it reaches him. It is best to send the mixture down in buckets or canvas bags, but if large quantities are required an enclosed chute may have to be used. When using a chute, the mixture should be sent down in large quantities at a time and not in dribs and drabs.

Where there is no support for the mixture a rough timber box should be constructed and firmly fixed around the space to be filled. Materials sectionally large enough to support the weight of the mixture must be used until it sets, and it should be borne in mind that when dry the aggregate weighs approximately 30 cwt per cu. yd and the cement approximately 23 cwt per cu. yd; it will therefore be seen that stout timber, well shored and supported, will be required.

Application. To close gaping fractures with cement the first of the mixture is usually sent down to the diver in bags, which are then 'middled' and wedged in the fracture so that each bag is half-inside and half-outside. When the aperture is thus closed the remaining space is filled in and the whole then shored up. If a large space is to be filled in, much time and material can be saved by packing it with handy-sized pieces of rock, provided that they are then well bonded into the concrete.

To stop small leaks with concrete while they are still under pressure the leakage must first be reduced to a minimum by plugging, and then a drain must be provided to carry away the water until the cement is set. A rough water-course should be constructed in the ship's bilges from the damage to the limber-holes, and for boxes a drainpipe or pipes should be provided. The cement is then applied in the usual way, time being allowed for it to set; it is then well shored and the drains are securely plugged.

If large cement boxes are being constructed over the inside of temporary patches to provide additional strength for long sea passages, or against damaged bulkheads for stiffening them, additional reinforcing with odd sections of steel will greatly add to their strength.

Concrete is of little use for a structure which is liable to 'work' in a seaway. It does not bind well with steel which is contaminated with oil, and is most satisfactory on lightly rusted surfaces. If there is any likelihood of grease or oil on a surface which is to be covered with concrete, the surface should, if practicable, be cleaned with petrol or a hot solution of soda.

Use of compressed air

Compressed air is extensively used in salvage operations for driving under-water tools, pumps and other equipment, and it can also be used in certain circumstances to recover buoyancy in flooded compartments which cannot be pumped out. By sealing the flooded space and introducing air under pressure the water is forced out through the fractures, and so buoyancy is restored. The use of compressed air for this purpose in merchant vessels (except in oil tankers) is limited, because their cargo-holds have large hatches and numerous openings which can only be sealed by very extensive work. In cargo-vessels, therefore, compressed air is only of use in tanks and spaces which are constructed as dry tanks, ballast tanks and oil tanks.

Compressed air can be of considerable value for recovering buoyancy in double-bottom tanks which have been damaged by grounding, but it should be used with discretion, because building up sufficient pressure in the tanks to expel the water exerts a considerable strain on the tank-tops. The tank-tops of merchant vessels are constructed and tested to withstand a pressure-head of water equal to that on the bottom-plating when the ship is fully loaded, so theoretically there should be no risk of damage in building up such an air-pressure; in a ship with heavy bottom-damage, however, it should be assumed that the tank-top also may be strained and weakened, and so it must only be submitted to any additional stress with great care. The ship may also be floating at a greater depth than is normal owing to flooding, and if, therefore, it is considered that there is any risk of damage to the tank-top by the use of compressed air it should be well shored. In the holds of a fully-loaded vessel the

risk of damage will be greatly reduced, as her cargo will help to prevent any tendency for the plating to lift when air is forced into the tanks. The usual method of admitting compressed air into a double-bottom tank is by means of a flexible pipe tightly fixed into a wooden plug, which is driven into the 'breathing-pipe' of the tank. If possible, a pressure-gauge should be provided to indicate immediately if the air-pressure is excessive or the water is not being freely displaced.

Oil tankers, with their numerous easily-sealed compartments, are particularly suitable for the use of compressed air. The tank-lids are so constructed that they are airtight when closed. There are valves which can be closed in the gas pipelines, and the oil compartments are virtually sealed whenever they are filled.

AID TO VESSELS BEACHED OR STRANDED

Beaching a ship

If a vessel is so heavily damaged that the leakage cannot be brought under control she should be beached, if possible. For remarks on how to beach a damaged vessel see page 129. In tidal waters it is better to allow the vessel to ground on a falling tide than to drive her on to the beach. How far up she is beached depends on many factors, such as the range of the tide, whether it is necessary for the damaged places to be uncovered at low water, and the estimated time it will take to repair the damage. But the vessel should not be beached too far up, because this may make refloating her unnecessarily difficult.

Securing a beached or stranded vessel

When a vessel is beached or stranded the first task is to secure her so that she will neither be driven further onshore by the tide or bad weather, nor suffer further damage by pounding in a swell or in heavy seas, nor be slewed broadside on to the waves.

Use of anchors and cables. A vessel is best secured with her anchors and cables laid out with as much scope of cable as possible and backed as necessary by other ground tackle. It is emphasised that any ground tackle used should be as heavy and as strong as possible and laid out with as much scope as possible, because the stresses to which it will be subjected are far greater than normal, for the reasons described below.

When a vessel is riding normally to her anchor in a heavy sea she is not forced to leeward by the waves, but merely rises and falls on each wave as it passes her. As she rises on the crest of each wave she will surge ahead a little and then drop back as she falls in the trough; this surging, combined with the spring in the bight of the cable, prevents sudden and heavy stresses being transmitted to her anchor. When waves break against a vessel aground in shallow water, however, they exert a considerable force, tending to push her farther shoreward, and to prevent this the cables of any ground tackle holding her must be hove as taut as possible; there is then no bight in the cables to absorb any sudden stresses. Furthermore, that part of the vessel which is seaward may be waterborne and so may tend to rise and fall with the passing of each successive wave, but because the vessel is aground she cannot surge, and so the extra stress is transmitted through the taut cables to her anchors. This extra stress may have one of two

results: if the ground tackle is not heavy enough or strong enough either the anchors will drag or the cables will part; if, however, the ground tackle is sufficiently strong and heavy the vessel may be dragged seaward little by little as each successive wave passes, until the cable is sufficiently slack for its bight to absorb the extra stress. When securing the vessel in a swell the cables of her ground tackle must therefore be sufficiently slack to absorb any extra stresses as the vessel rises and falls, but not too slack, otherwise the waves will slew her bows round. When refloating the vessel, however, these extra stresses can usefully be employed to haul her off, simply by keeping the cables as taut as possible.

When laying out ground tackle, the anchors should be placed, if possible, in the best positions both for holding the vessel and for hauling her off.

Scuttling. If the available ground tackle is insufficient for holding the vessel she should be scuttled, and sufficient compartments flooded to hold her steady. Scuttling a vessel will also prevent her from lifting and pounding in a heavy swell. The best method of scuttling is to burn holes with an oxy-acetylene burner in the ship's side above the turn of the bilge between frames and as close to the low-water mark as possible. If oxy-acetylene plant is not available explosives may be used, but any holes thus made will have to be patched and made good again before refloating, so small charges only should be used. The selection of the compartments to be flooded in a merchant ship will necessarily depend on the nature and amount of cargo in the holds, and little guidance can be given in this respect; usually flooding two holds will be sufficient to keep a vessel steady, but more may have to be flooded if the weather is bad.

Use of small vessels or craft for dredging

When a vessel is aground on a soft bottom, sand or mud may silt up around her to such an extent that even when lightened she cannot be hauled off. In such a case the use of small craft for dredging away the silt by means of the wash from their propellers has proved very effective where the nature of the bottom is suitable.

Dredging by this means may be used for three different purposes: to scour away the sea bed under a stranded ship so that she can settle down deeper and so become waterborne; to dredge a channel seaward through which the ship can be moved to deeper water; and for tunnelling cavities under a beached ship to enable a diver to effect repairs. This type of dredging is effective where the bottom is of sand, soft mud, mud and sand, or shingle and stones, but is useless where the bottom is stiff clay. Disappointment may be experienced where the bottom consists of a layer of sand or silt one or two feet thick which is easily washed away but has hard, stiff clay or rock under it.

The most suitable type of vessel likely to be available for dredging would be a twin-screw tug drawing about 12 ft 6 in. aft and 9 ft forward, but a single-screw trawler or similar handy vessel will serve.

Before starting dredging operations an accurate plan of the area around the vessel must be made and frequently checked as the work proceeds, otherwise the displaced silt may settle and bank up in inconvenient places. Dredging craft have, in fact, been known to pen themselves in with banks of their own creation. Such banks are, however, more easily dispersed than the undisturbed sea bed, particularly at full ebb or flood.

The depth at which dredging is effective depends upon the power of the dredging craft and the nature of the work; for dredging a tunnel right under a vessel from one side to the other a powerful craft could not work effectively in a depth more than 6 ft greater than her normal draught, but when it is only desired to free mud from under the bilges of the vessel and not to extend the dredging as far as her keel, dredging has been effective in depths up to 26 ft.

Scouring away the sea bed. As an example of the use which can be made of craft for dredging purposes let us take a ship lying evenly aground on slightly shelving sand and which cannot be moved by her own power, or with ground tackle or by towing. Lightening her can still be tried, but as this would probably involve delay and the expense of obtaining a suitable ship for transhipment of cargo, dredging should first be attempted. Before starting operations the stranded ship is secured with efficient ground tackle. Two dredging craft are employed, suitably trimmed by the stern and each moored for dredging with both bower anchors laid out with a good scope of cable and well spread. The craft then back into position, both on the same side of the ship, one abreast the foremast and the other abreast the mainmast; their sterns are then secured close to her side, using a strong hawser on the towing-hook which is taken right across the deck of the ship and made fast to a suitable point on the opposite side to obtain as much scope as possible; if there is any sea a short towing spring will have to be used and reasonable clearance from the ship allowed. If there is not much current the foremost dredging craft is secured at an angle of about 70° to the fore-and-aft line of the ship, with her stern directed towards the bow of the ship, and the after craft is secured at the same angle to the fore-and-aft line but with her stern directed towards the ship's quarter.

Manila springs are led from each quarter of the dredging craft through convenient leads to winches in the stranded ship so that the craft can be gradually hove along the ship's side as dredging progresses, and headropes are also run out for altering their angle of inclination. If the depth of water alongside the ship is such that the propeller of the dredging craft is near the bottom, her stern can be held against the ship's side so that her propellers will be about 8 ft clear, but in deeper water a greater clearance, say 12 ft, must be allowed and the trim of the dredging craft by the stern must be increased as much as safety will permit.

The general object is to tunnel completely under the wreck, if possible, and it is a gratifying moment when, perhaps after an hour or two of work, a sudden blow-through of sand, mud and seaweed appearing in the water on the far side of the ship shows that this has been accomplished. With hawser and springs in position, it is well to start slowly and adjust the strain on all parts; too violent disturbance of the sand may cause choked condensers. The positions for the first effort might be chosen in way of the foremast and mainmast so that removal of the sand from underneath should not throw an undue strain on the hull. If the dredging craft are held at too fine an angle, the flow of water will be deflected along the side and bilges of the ship instead of scouring in underneath her bottom. Once the silt is blown through to the other side, the stern of the dredging craft should be gradually fleeted along to widen the cleared area without deepening it unduly and so perhaps straining the wreck. It is important to maintain the flow of water completely under the ship and not to allow it to be deflected so that the gap closes and a fresh start has to be made.

If it is impossible to tunnel completely under the ship, the dredging craft must be stationed one on each side of her, and must work persistently from amidships to the bow and from amidships to the stern, while keeping themselves at an angle of from 30° to 40° to the ship, so drawing or sweeping the sand along. This will not only free the ship's bilges but will also scour the sand away on each side of her bottom, and so leave the ship resting throughout her length on a ridge of sand. The ship can then be freed by working her engines ahead with the rudder hard over first one way and then the other, and also by heaving in on either bow or quarter to haul her off the ridge. When thus dealt with, a ship usually begins to swing a degree or so, this arc increasing gradually until she frees herself. As a rule, the engines should not be driven astern, because this may bank up the sand around her and choke her condensers. Two dredging craft are not essential, but they do accelerate the work. With a vessel aground by the head on a steep bank one dredger may be used on each bow. Sometimes one craft may be moored to do the actual dredging while the other is used to fan away and disperse the silt.

Dredging a channel. When dredging a channel through which to haul out a stranded ship it is usual to start at the deep-water end with the dredging craft moored stern towards the ship and held in position by a dredging hawser (say 3 in. F.S.W.R.) led from the ship. The dredging should, if possible, be made fast in the dredging craft somewhere near her pivoting point, otherwise her stern will be girded and prevented from slewing. The strain is taken on the dredging hawser and the engines of the dredging craft are worked ahead, and as progress is made the cable of the dredging craft is veered and the dredging hawser hove in. If the dredger is kept on a dead straight course the channel would be only about 6 ft wide, so her stern is very slowly slewed from side to side by using her rudder, thus widening the channel and at the same time banking up the silt on each side. Frequent soundings are taken to check progress, and the course of the channel is well buoyed. On reaching the ship she is dredged free and swung into the channel in the manner already described.

HAULING OFF A STRANDED VESSEL

When a ship is fast aground it is better to rely on strong and well laid-out ground tackle to haul her off than on tugs to tow her off. The most powerful tugs can exert a pull of some 40 tons on a towrope, but there are very few tugs of this power, and the average rescue tug can only exert a pull of from 12 to 15 tons (see page 132). Far greater forces than these can be exerted by strong ground tackle rigged with heavy purchases. Furthermore, in a swell a tug cannot keep the towrope sufficiently taut to take advantage of any extra force obtainable as the vessel rises and falls on the waves, whereas with strong ground tackle this extra force can be usefully employed to haul the vessel seaward.

Before laying out the ground tackle it will be necessary to consider the best direction in which to heave the ship off, and whether she will refloat more readily bows or stern first. Broadly speaking, it is usually best to bring the vessel off bows first, because most ships are usually deeper in draught aft and so the bows can be more readily moved.

Usually the most difficult part of any heaving-off operation is to slew the vessel head or stern to the sea, but once this is done she can usually be refloated by perseverance and hard work. As soon as the vessel is end-on to the sea the position is much improved, because she will be far less vulnerable to any subsequent bad weather, and by flooding-up and holding her securely by the ground tackle it should be possible to weather any but the worst of storms. Ships which have been driven ashore when lightly laden can often be assisted by gales once the preliminary work has been completed, because a heavy swell running in on a beach will help to lift her, and as she lifts a very great stress will be brought on the ground tackle and so cause the vessel to surge seaward with each lift. In such cases it is most important to keep a heavy strain on the ground tackle, otherwise the seas will tend to swing the ship broadside on to the beach again instead of working her slowly seaward.

Ground tackle is therefore usually rigged with strong purchases so that it can be subjected to heavy stresses and kept as taut as possible. Rigging these purchases leaves much scope for improvisation, because usually only salvage vessels and bases have all the necessary gear. But very considerable stresses are set up during these operations, and the normal deck fittings are not sufficiently robust to use either as anchorages for the standing blocks of purchases, or for the stoppers used when fleeting the purchases.

To illustrate some of the methods used to refloat a stranded vessel, descriptions of actual incidents are given in the following pages. These have been selected because it is considered that they are normal refloating operations without any great complications, and of the kind likely to be encountered by seamen.

Example 1. HEAVING OFF A SHIP HARD AGROUND ON A TIDELESS SANDY BEACH

Circumstances

This case was that of a merchant ship of 5,780 tons gross, 449 ft in length and of 58 ft beam. The ship was driven ashore in bad weather on to a firm, sandy beach with isolated patches of submerged rock. She was lightly laden, having only water ballast in the double bottoms and 300 tons of shingle in No. 5 hold. On first grounding, the vessel pounded on the beach, the heel of her stern frame was fractured, and she was holed in No. 4 double-bottom tank and in the port bilge of No. 4 hold, which hold flooded to water level. A rescue tug managed to pass a towrope across to the ship while the gale was still blowing, but the weight of the water in her after end and the force of the seas striking her broadside prevented refloating her, though the tug's efforts probably stopped her bow from being driven further ashore.

As soon as the weather moderated, an inspection was made and it was found that the vessel was hard aground along her entire length; there was just sufficient water under the bows to refloat her, but she was 2 ft 6 in. short of her floating draught on grounding at the after end. There was nothing to obstruct her being hauled off bows first, so ground tackle was laid out for this purpose. No anchors were laid out to hold her stern, because it was considered that the weight of water in No. 4 hold would restrain her after end from driving further ashore in any subsequent bad weather. The tidal range was only a few inches, so no assistance could be expected from the rise.

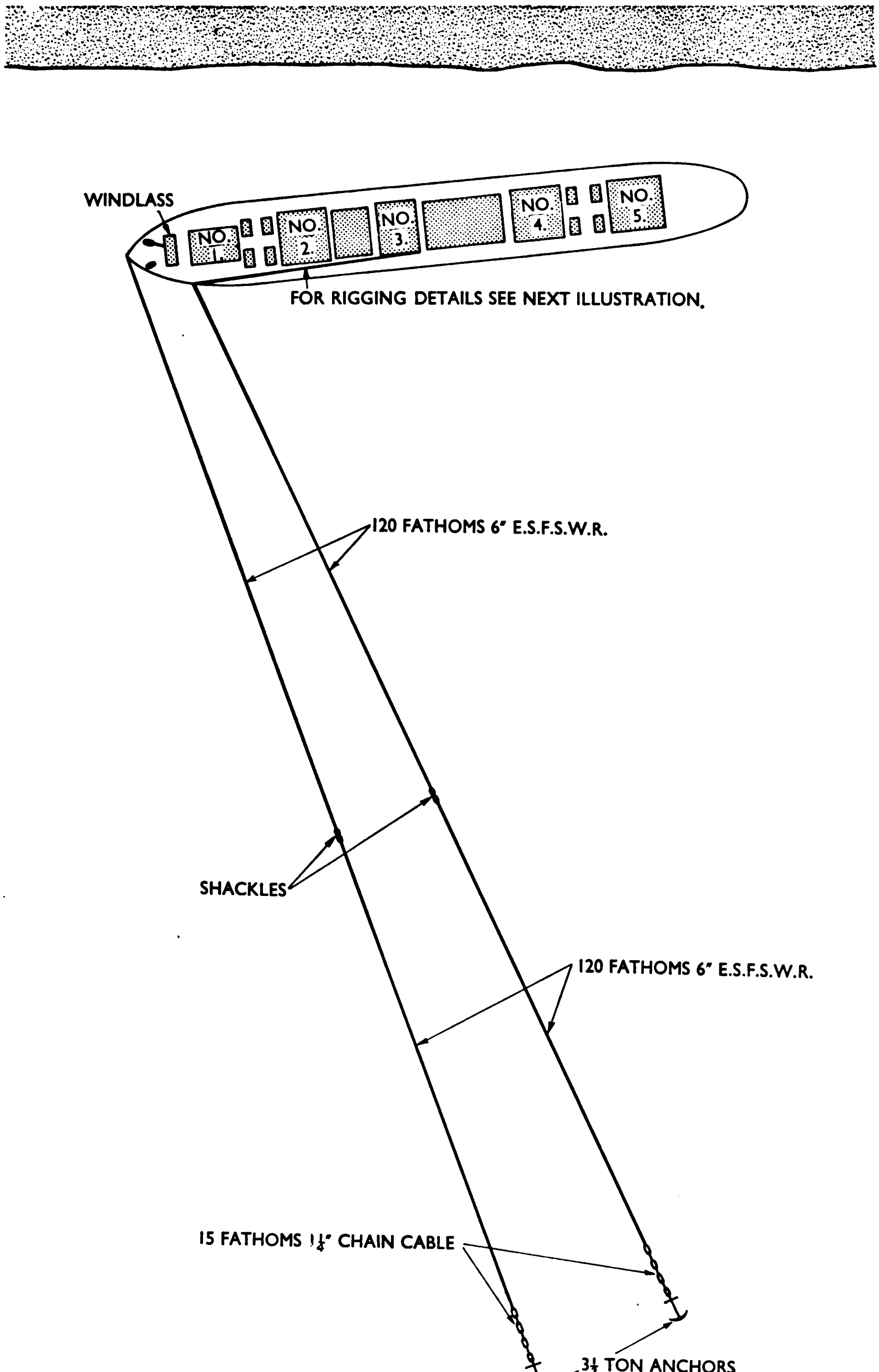


FIG. 7–6. Example 1. Layout of the ground tackle for hauling off the stranded vessel, bows first

Preparations

A $3\frac{1}{2}$-ton anchor with 15 fathoms of $1\frac{1}{4}$-in. chain cable shackled to two 120-fathom, 6-in. E.S.F.S.W. hawsers (shackled together) was laid out to provide the main anchorage for the heaving-off gear (fig. 7–6). The ship end of the combined hawser was brought in through a Panama fairlead forward on the main deck and connected by a Carpenter's stopper to a four-fold, 40-ton purchase rove with a $2\frac{1}{2}$-in. E.S.F.S.W.R. fall which was taken to a 5-ton winch abreast No. 3 hatch. This purchase was anchored by a strop made of several turns of $3\frac{1}{2}$-in. E.S.F.S.W.R. around the coaming of No. 3 hatch and the forward Samson post at No. 3 hold. An additional stopper to hold the hawser while overhauling the purchase was secured around the base of the winches at the after end of No. 1 hatch (fig. 7–7).

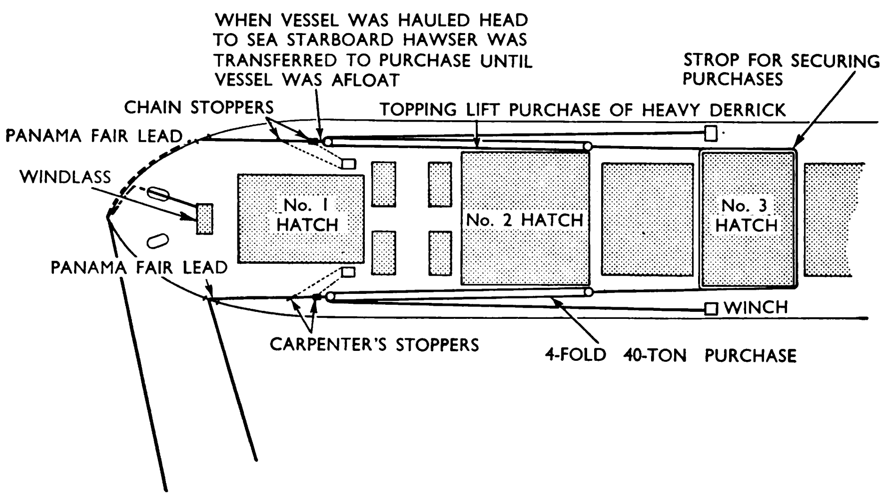


FIG. 7–7. Example 1. Layout of gear in the stranded vessel

Another $3\frac{1}{2}$-ton anchor, with similar lengths and sizes of chain cable and wire hawser, was laid out and the ship end of this hawser was brought round the bows and up through the starboard hawsepipe to the windlass on the forecastle head (fig. 7–7). The purpose of this second anchor was to provide a means of hauling the ship clear of the beach quickly when she refloated, and so prevent her from sustaining further damage by pounding. It was expected that the vessel would have to be refloated under adverse conditions because there were no facilities for the discharge of the ballast; and even if her ballast were discharged, she would still be short of water to refloat.

A portable salvage pump of 120 tons-per-hour capacity was placed on board and rigged in No. 4 hold, and this, with the ship's bilge pump, proved sufficient to overcome the leakage.

Execution

When all was ready, No. 4 hold and all ballast tanks which could be pumped out were emptied and a heavy strain set up on the anchor hawsers, these being hove in slowly until all the gear was 'bar-taut'. After the strain had been kept

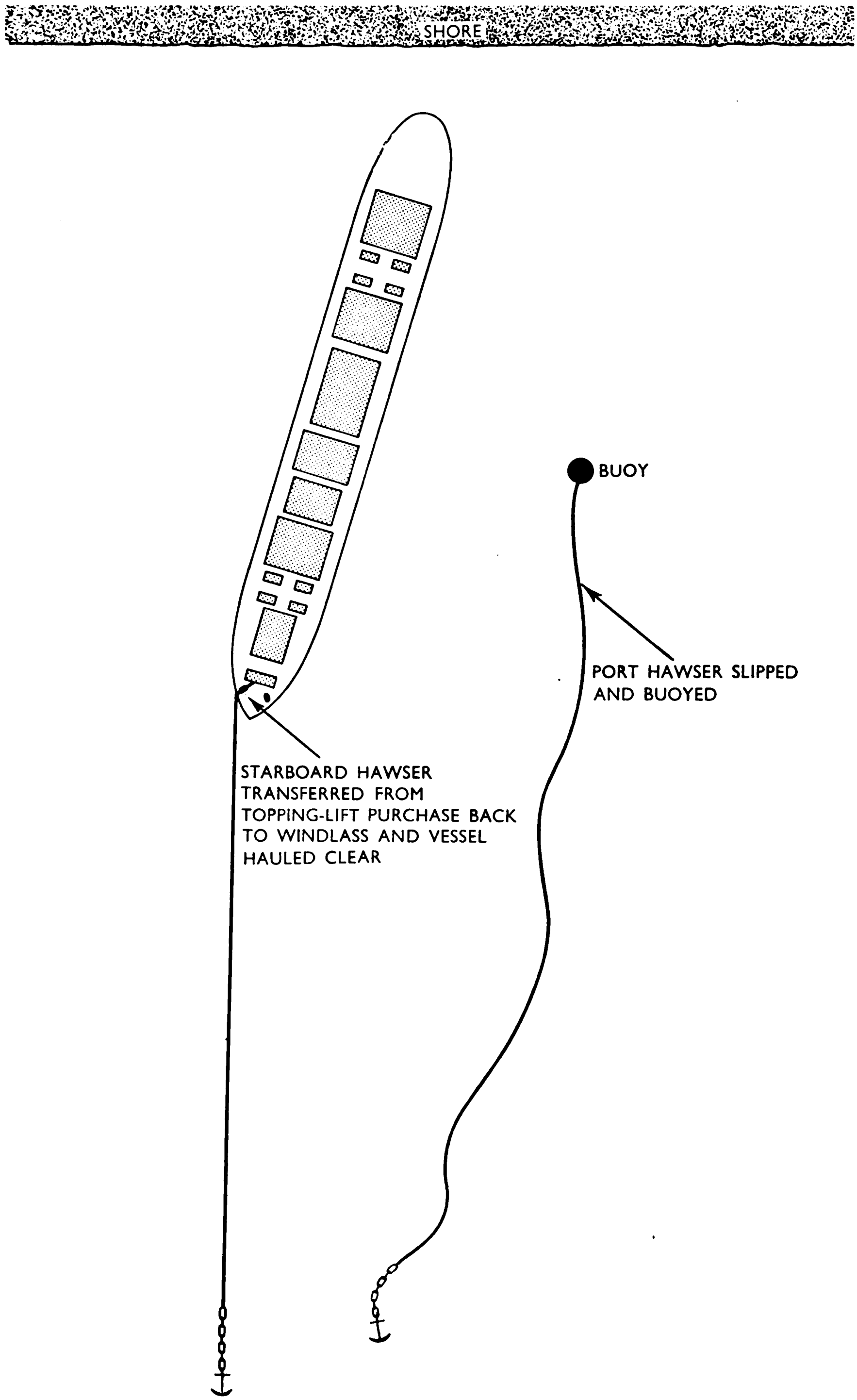


FIG. 7·8. Example 1. Final stage in refloating the stranded vessel

up for six hours the vessel's bow was hove round, and once it started to move the slack came in quite well until the ship was heading out to sea. No further movement was obtainable and there was now 8 in. of water under the stem, but still 2 ft 6 in. less than the floating draught under the stern.

The heavy strain on the ground tackle was maintained constantly for the next three days without result. During this period the leaks in No. 4 hold were reduced by plugging them with wooden wedges, etc., but no attempt was made to effect more permanent repairs because it was considered advisable to retain some means of flooding-up should the weather deteriorate.

The 6-in. hawser from the second anchor was then unrove from the starboard hawsepipe and led in through the foremost Panama fairlead on the starboard side, where it was connected to a topping-lift purchase off one of the ship's heavy derricks, rigged in a similar manner to the 40-ton purchase, thus providing a greater heaving power than that provided by the windlass. No Carpenter's stoppers were available for this second set of gear, and consequently the purchase was secured by means of a heavy chain stopper, a similar stopper being rigged for use when overhauling the purchase (fig. 7–7).

The next day the weather was bad, with heavy seas running in on the beach. The wedges were knocked out of the leaks in No. 4 hold and all ballast tanks which had been pumped out were flooded up. No attempt was made to heave the ship off, but any slack which became apparent in the gear was taken up and the hawsers were constantly attended to prevent undue chafing in the fairleads.

The weather remained unsuitable for the next two days, but then the wind began to drop and the sea moderated. As soon as the sea had abated sufficiently the ship was again lightened and heaving-in was resumed. As the bows of the ship lifted in the swell heavy stresses were brought on to the gear and gradually, inch by inch, the vessel began to work to seaward. Some twelve hours later the slack began to come in quite well, indicating that the vessel was nearly afloat. The starboard purchase was then disconnected and the starboard hawser brought back through the hawsepipe to the drum of the windlass while heaving on the port hawser was continued. Shortly afterwards the stern became free and the ship was hove clear by the windlass and the starboard anchor-hawser. The purchase was disconnected from the port hawser, which was slipped and buoyed (fig. 7–8), and tugs were sent for to tow the ship to a nearby port. While waiting for the tugs the ballast tanks were flooded-up, and the leaks in the bilge of No. 4 hold were stopped by means of wedges and plugs. A drain was left from the affected bilge pockets, which were then filled with concrete, and when this had set the limber holes were plugged. The vessel was then towed to the repair port without any further repairs being required.

Example 2. SALVAGE OF A VESSEL DRIVEN ASHORE BETWEEN TWO ROCKY LEDGES

Circumstances

A merchant ship of 2,883 tons gross, 315 ft in length and of 46 ft beam, proceeding in ballast during exceptionally heavy weather, found it impossible to keep off a lee shore. Visibility was bad, but the master selected a place where there was a break in the heavy surf and ran his ship ashore, hoping that she

would find a quieter resting-place than appeared likely if she were driven ashore as the wind and sea dictated. The crew were successfully landed by breeches-buoy and the vessel was left until the weather moderated. A few days later a small salvage party boarded the ship, which was found to be lying in a small cove on a flat shelf of rock between two outlying reefs (fig. 7–9). The port side aft was against one of the reefs, which had prevented her from swinging broadside on to the sea, so the ship was still lying stern to sea, having swung only a few degrees since she was run ashore. At high water the fore part of the ship was afloat, only the stern being hard aground. Had it been possible to swing the ship through 16 points bow to sea she could have been trimmed bow-down and easily refloated; but the high rocks on each side made this impossible, and it was evident that she would have to be refloated stern-first, a much more difficult operation because there was 1 ft 6 in. less water aft than this required. At low water the vessel dried out almost for her entire length and a survey revealed that there was heavy damage throughout her bottom and that her rudder post and rudder had carried away and were lying close alongside under the starboard quarter. The after peak, all double-bottom ballast tanks and the shaft tunnel were open to the sea, and it was evident that no repairs to recover buoyancy in these compartments could be carried out. Apart from minor leakage from the shaft tunnel into the after holds, the rest of the ship was dry. By using salt water in the boilers it was possible to provide steam for working the winches.

Preparations

The holding ground offshore was known to be poor, so arrangements were made to lay out a good scope of cable on the anchors for hauling the ship off. The services of a shallow-draught coastal vessel were obtained, and 360 fathoms of 4½-in. wire hawser were faked down on her deck. In fine weather this coaster approached as close to the stern of the ship as possible and passed the end of the hawser on board the port quarter by means of a messenger; the coaster was then backed out seaward as she payed out the hawser, taking care to keep it taut. To the end of this hawser a 3½-ton anchor was shackled, and this was backed up by another 3½-ton anchor secured to the first anchor by a length of chain cable. A similar arrangement of ground tackle was laid out on the starboard quarter of the wreck and purchases rigged in the manner described below were connected to the hawsers of each set of anchors. A rescue tug was also available, and so an additional 360 fathoms of 3½-in. wire rope was laid out and buoyed off to serve as a towrope.

The ship was a well-deck ship of the 'three-island' type, with cargo winches abaft the accommodation housing amidships above the main deck, and these were used for hauling on the purchases. Two four-fold purchases, rove with 2½-in. wire falls, were rigged above the after well-deck, one on each side, from the after end of the midship housing to the fore end of the poop deck (fig. 7–9). Their standing blocks were anchored by a strop made of strong wire rope which was passed right round the midship housing, wooden chafing blocks being placed as necessary to prevent the strop from chafing on the sharp corners. Their moving blocks were attached to the 4½-in. anchor-hawsers by means of Carpenter's stoppers, and two additional Carpenter's stoppers were provided on the poop, anchored by several turns of 3½-in. wire rope around the poop housing to hold the anchor-hawsers while overhauling the purchases. The

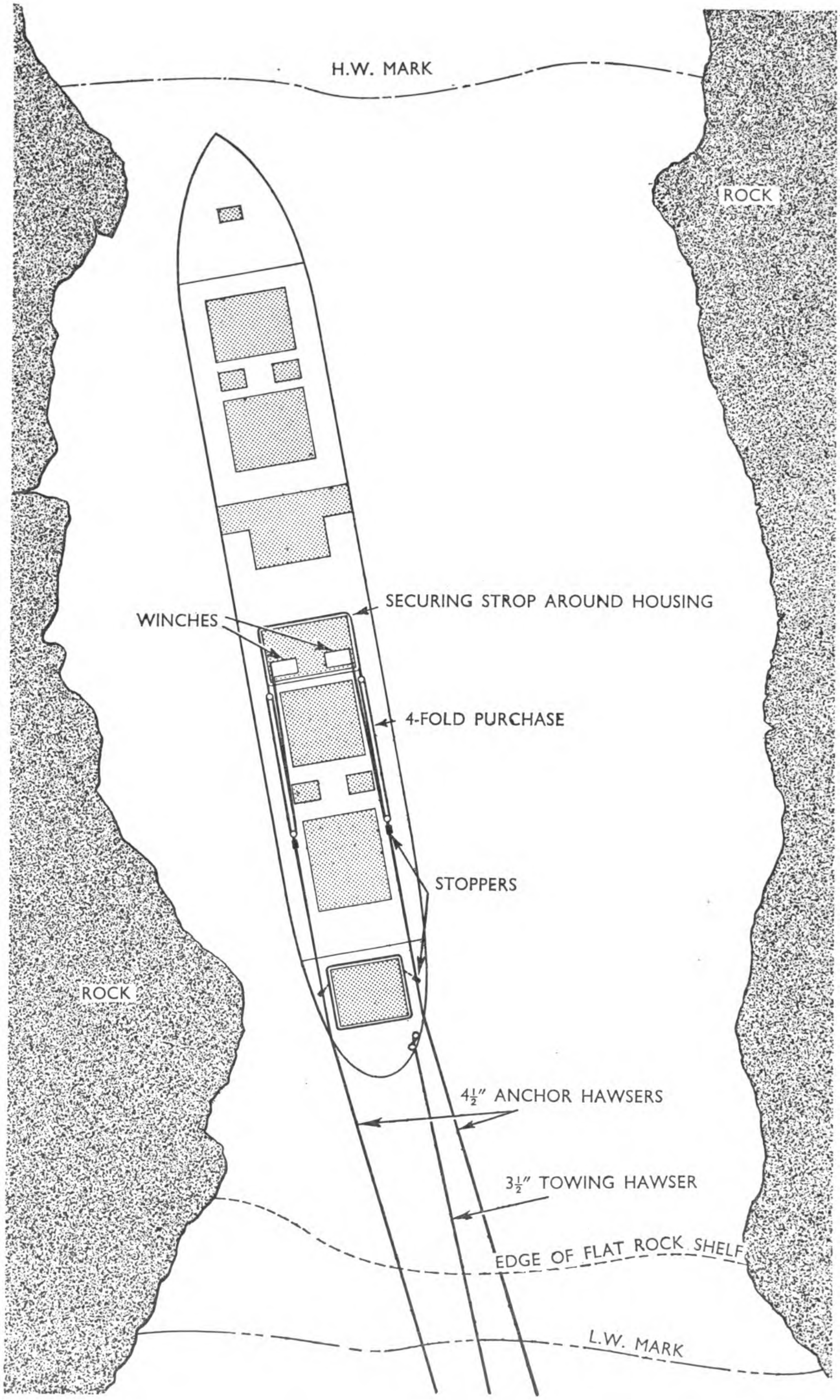


FIG. 7–9. Example 2. Position of stranded vessel and layout of ground tackle for hauling her off

position was then as illustrated in fig. 7–9, and the advent of spring tides to assist the operations was awaited.

It was thought that extra pumps might be needed should further damage ensue during refloating. No small portable pumps similar to the 70-ton electric and diesel pumps used in the Royal Navy were available; only large petrol-driven salvage pumps could be obtained in the vicinity, and their transport to the site presented some difficulty. Finally, however, as it was considered to be essential to have them, it was decided to ferry them by motor-launch from a vessel offshore. This was successfully accomplished and the pumps were hoisted on board by the ship's own derricks, and rigged in her forward and after holds. All was now ready for an attempt to refloat the ship.

Execution

As soon as the tides served, heaving-in was started and continued from well before until well after high water. The rescue tug picked up the towrope provided and every means of moving the ship's stern to seaward was exerted. A few feet of hawser were gained during the first attempt, but it was impossible to tell whether this resulted from the anchors dragging or whether, in fact, the ship had moved. At low water, an inspection of the stern from the rocks showed that the ship had moved some eight or ten feet in the required direction and that the rock on which she was resting was cracking and breaking up under the strain. To assist the disintegration of this rock, wire hawsers were run from each bow of the ship to other rocks inshore to enable the ship to be slewed on her heel during the high-water period when she was afloat forward.

Further heaving was carried out during the next high water, and an inspection at the subsequent low water revealed steady progress in the desired direction. The depth of water at the stern had now been increased by some nine inches and it was confidently expected that the operations would be successful before the spring tides began to fall away. Again, at half-tide on the next tide, the work was resumed and the anchor hawsers were steadily hove in by inches. At approximately half an hour after high water the remaining ledge of the shelf of rock gave way and the vessel slid seaward and was towed between the reefs into deep water. The slewing hawsers at the bows and also the port anchor hawser were slipped. The starboard anchor hawser fell slack when the ship moved seaward and then fouled some rocky outcrop on the bottom and brought up, leading shoreward. The stopper was jammed shut and could not be released, so the fall of the purchase had to be slipped and allowed to unreeve. The anchor hawser then went by the board with a run, complete with the moving block of the purchase, causing some confusion on deck but fortunately no damage or casualties. The towrope was then transferred to the bow and the vessel successfully towed to the nearest port, where she was handed over to the repairers for docking.

In both the foregoing examples of salving stranded vessels, which may be taken as being typical of such operations, success depended on the ability of the stranded vessel to supply steam. In similar instances where no steam was available a vessel has been salved just as well by operating her winches by compressed air supplied by portable compressors placed on board; and in extreme cases, where no power was available, the vessel has been hauled off by

rigging additional purchases luff-upon-luff and using manpower only. This latter course, although proved possible with ships of up to 5,000 tons gross, is not recommended because it involves extremely trying and exhausting work for large numbers of men, but it should never be ignored as a last resort. The average ship's winch will function fairly efficiently on compressed air, but attention must be paid to oiling the cylinders, and for this purpose a light engine oil should be used.

Example 3. SALVAGE OF A SHIP WHICH WAS SILTED-UP AND WITHOUT POWER

Circumstances

This example differs from the other two in that dredging was used to free the ship from silt which had banked up round her, and another vessel moored offshore was used to haul her off because there was no power in the stranded vessel to work her windlass and her winches.

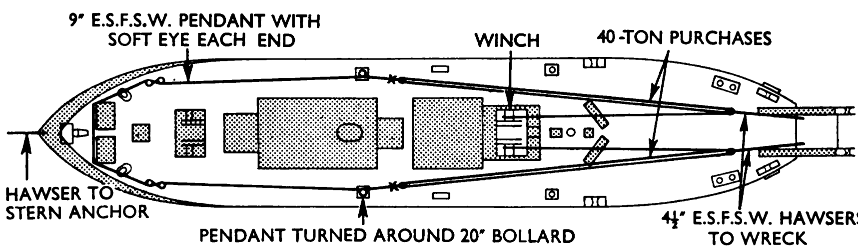


FIG. 7–10. Example 3. Layout of the gear on board the boom-defence vessel for hauling off the stranded ship

A boom-defence vessel of the *Bar* class was used for hauling-off. Any other type of vessel can, however, be used equally well for hauling-off purposes provided that she is equipped with winches, that she has sufficient deck space for working the necessary purchases, and that anchorages of sufficient strength to hold the purchases can be devised.

The stranded ship, a vessel of some 1,800 tons gross, had been washed high up on a soft, sandy beach in bad weather, and a sandbank about four to six feet high had formed on her seaward side. The tidal range was only 14 inches, and at high water the depth on the inshore side was two feet less than that required to refloat the ship. The ship was fully laden, but even if totally discharged she would still not have been able to ride over the bank formed on her seaward side. Furthermore, lighters for discharge were not available and the value of the cargo precluded any suggestion of jettisoning.

Preparations

The boom-defence vessel was moored by means of her 60-cwt stern anchor at the full scope of the 4½-in. E.S.F.S.W. stern-anchor wire, and two 4½-in. E.S.F.S.W. hawsers, each 120 fathoms long, were passed from her to the ship. The end of each hawser was connected in the boom-defence vessel to a 40-ton purchase rigged as shown in fig. 7–10, and the other end was secured in the ship

by reeving it, twice, up through one hawsepipe and down through the other, and then shackling it to its own bight. Heaving in alone was attempted during a brief period of suitable sea conditions with a fairly heavy swell, but without result; so it was decided to try dredging, using the propeller stream from another craft, as described earlier in this chapter.

Dredging

A small diesel harbour tug was used, and as much pig iron ballast as practicable was placed on her after deck. A suitable anchor shackled to a length of 3½-in. E.S.F.S.W.R. was laid out to moor the tug, because her cable was not long enough for this purpose. Another 3½-in. wire hawser, led from the towing hook, was used to secure the tug to the ship, and warping hawsers were provided from each quarter of the tug to enable her stern to be fleeted to the required position. The tug was able to back in to within some 20 ft of the ship and was moored about amidships at an angle of 30° to 40° to the latter's fore-and-aft line, her own stern being directed towards the bows of the ship. It was not intended to dredge right under the ship but merely to disperse the bank of sand which had been formed and free the ship's bilge sufficiently to enable her to be swung free by heaving in from the boom-defence vessel. Dredging was started, and the stern of the tug was worked from amidships to the bows of the ship to fan the dredgings around her stem clear of the arc through which she was expected to swing. With each fleet the tug dredged some three to four feet off the bank, and she was progressively hove astern until she was working close alongside the ship. Dredging was continued until the sand was scoured away for some six or seven feet under the ship's bottom. It was found necessary at frequent intervals to transfer the tug to a position off the ship's bows to clear away banked sand, because silt tended to be deflected from the ship's side and to settle some 12 ft seaward of her bows.

After some 16 hours of continuous work the whole of the seaward side of the ship, from amidships to her bows, was cleared to a depth of some 4 ft below her bottom. The tug was then repositioned to work from amidships to the stern in the same manner, and equally successful results were obtained.

A similar tendency for the silt to bank up on the seaward quarter of the ship was encountered, but it was found that this banking could be rapidly dispersed around the ship's stern by placing the tug in a suitable position. After about 12 hours of constant work on the after end a change of three degrees in the direction of the ship's bows was reported and the boom-defence vessel reported having gained some slack in the towing hawsers. These efforts were persistently continued and the ship was slewed gradually until she was lying head to sea. The ship was now afloat for two-thirds of her length from her bows aft, but her after end was still hard aground. The weather was calm, with no sea to assist refloating, so dredging was continued. The anchor of the tug was relaid to enable her to place herself at an angle of 20° to the fore-and-aft line of the ship, with her stern secured against the quarter of the ship. The engines of the tug were again started and kept going for the next six hours, until a blow of sand was reported from the opposite side. Simultaneously the ship began to move slowly seaward, and a few moments later she was well afloat. The tug was slipped and left to recover her anchor, while the ship was hove clear by the boom-defence vessel for towing away to the nearest harbour for discharge and repair.

EQUIPMENT AND VESSELS REQUIRED FOR MAJOR SALVAGE OPERATIONS

The examples given in the preceding pages described the successful salvage of stranded ships for which little specialised equipment was required. From a general-knowledge point of view, however, it is considered that a brief description of some of the methods used to raise sunken ships and of the special craft and equipment necessary for such major operations will be of interest and value to the seaman.

Cofferdams

When a vessel is sunk in shallow, sheltered water the usual method of raising her is to seal all except certain selected openings, repair the damage, and then build watertight, tower-like structures called *cofferdams* over the selected openings so that they extend from the hull of the ship to well above the surface of the sea. The necessary pumps can then be lowered down the cofferdams and installed inside them on the deck of the ship, and the ship is then raised by pumping her clear of water.

With merchant vessels the cofferdams are usually built up on the hatch coamings of the cargo holds, and timber is generally used in their construction because it is more easily handled by divers than steel. The cofferdam is built up on the coaming, plank by plank, and secured to upright supports fitted all round. The whole structure is then well braced and shored on the inside to enable it to withstand the external water pressure.

For success this method needs sheltered water, because cofferdams which can be erected by divers are not very robust and will not stand up to a heavy sea. The depth of water from which a ship can be raised in this manner is limited by the strength of her decks, because they must withstand a considerable pressure when pumping begins.

Pontoons

Where insufficient buoyancy is obtainable by pumping alone, *pontoons* or special *lifting craft* are used.

The Admiralty salvage pontoon consists of a horizontal steel cylinder divided into watertight compartments which can be flooded and then emptied by compressed air, and it is fitted at one-third of its length from each end with a vertical mooring-pipe which extends through it from top to bottom (figs. 7–11 and 7–12). For lifting work the pontoons are usually used in pairs, and the lifting capacity of each pair is about 160 tons.

Having decided on the number of pontoons required to raise the vessel, an equivalent number of heavy lifting hawsers are passed in pairs beneath her, spaced at suitable intervals along her length, and the ends of each pair are then rove through the mooring pipes of the corresponding pair of pontoons. The pontoons are then flooded-up and sunk, and the lifting hawsers are hove taut and secured by divers on top of the pontoons by means of special clamps resembling Carpenter's stoppers. When all is ready the buoyancy chambers of the pontoons are blown clear of water by compressed air, and the vessel is raised by the lift exerted by the now buoyant pontoons.

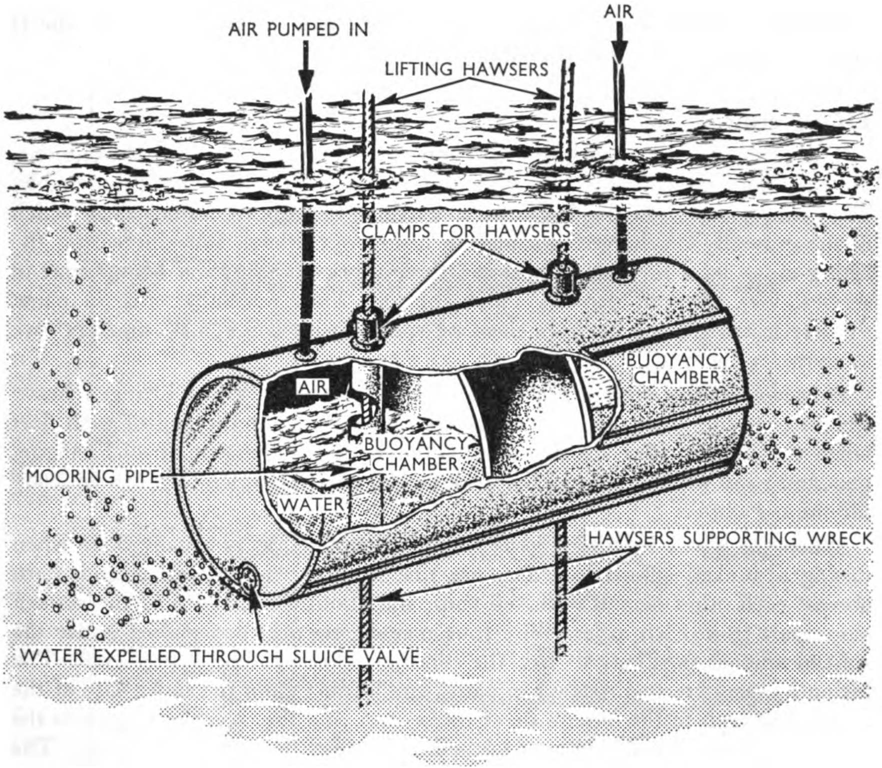


FIG. 7–11. Diagrammatic sketch of Admiralty salvage pontoon

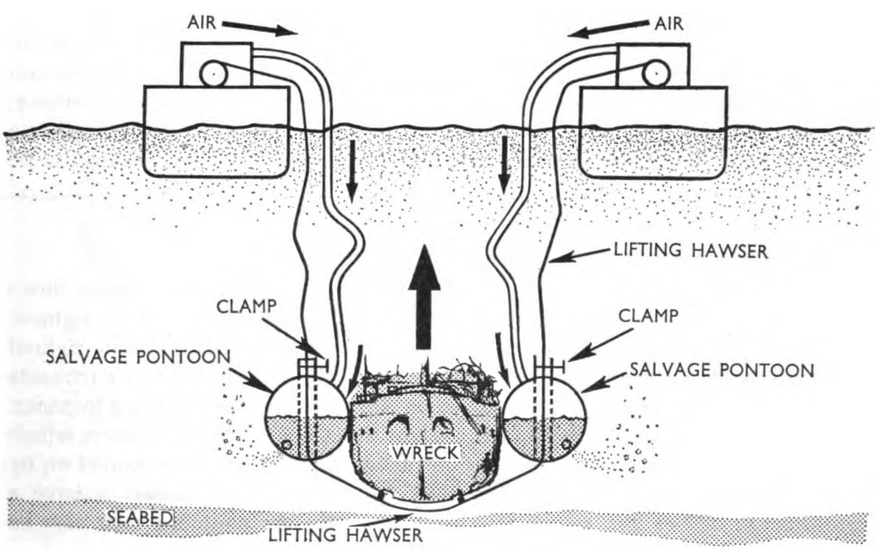


FIG. 7–12. A pair of buoyant salvage pontoons lifting a wreck from the sea bed

Pontoons are also used, secured firmly to the side of a vessel while she is being salvaged, to give her stability.

Lifting craft

The principle on which lifting craft operate is the same as that of pontoons, but they rely mainly on the rise of the tide for their lift and are not submersible. They can, however, be flooded down to a deeper draught by water ballast which is subsequently discharged during the lifting operations, thus increasing the lifting range by a few feet. There are three types of Admiralty lifting craft in service, viz: 600-ton, 750-ton and 1,100-ton. They normally work in pairs, the wreck being slung between them on special 9-in. E.S.F.S.W. hawsers rove as shown in fig. 7–13.

However, lifting craft are also capable of bow lifts. When lifting a heavy weight over the bows, 100-ton deck tackles are used. At the end of each fleet when the deck tackles are two-blocks, the weight is hung on special hanging pendants; and while it is hung the deck tackles are overhauled to get them ready for the next lift.

When the wreck is slung between two lifting craft, as is usually done when raising a sunken submarine, they are first securely moored head and stern abreast each other over the sunken ship, and about the breadth of the sunken ship apart from each other. Wire-rope messengers are then passed under the sunken ship at positions to suit the pinning points on the lifting craft. The lifting hawsers are then passed in pairs, one leading from the inner side of the first lifting craft to the outer side of the second, and the other leading from the outer side of the first lifting craft to the inner side of the second (fig. 7–13). The opposite ends of each pair of hawsers are then led across the deck of each lifting craft and clamped to each other by specially constructed clamps. At low water the pumping out of the ballast is begun, and as the lifting craft rise the hawsers are allowed to render a little in their clamps until they are all bearing an even strain; the clamps are then hardened down so that the vessel is lifted evenly on the rising tide. At high water the moorings of the lifting craft are slipped and the whole unit is towed inshore until the ship again grounds. Weather permitting, this procedure is repeated on each subsequent tide until the vessel reaches a beach or bank where she can be patched and made sufficiently seaworthy to be towed to the nearest dock.

Capsized vessels

Vessels which have completely capsized are sometimes floated upside down by means of compressed air, but generally a ship so raised cannot be righted, and is only fit for sale to shipbreakers. A vessel lying on her side can be righted by sealing and controlled pumping, water being left in selected compartments on the high side and buoyancy employed on the low side as the righting moment. Alternatively, she can be parbuckled upright by means of strong hawsers which are usually secured to levers built up on the ship's side, and then hauled on by means of purchases anchored to fixed points ashore. If the vessel is large a combination of the two methods is used, and salvage pontoons may also be secured to the low side to provide additional righting moment with their buoyancy.

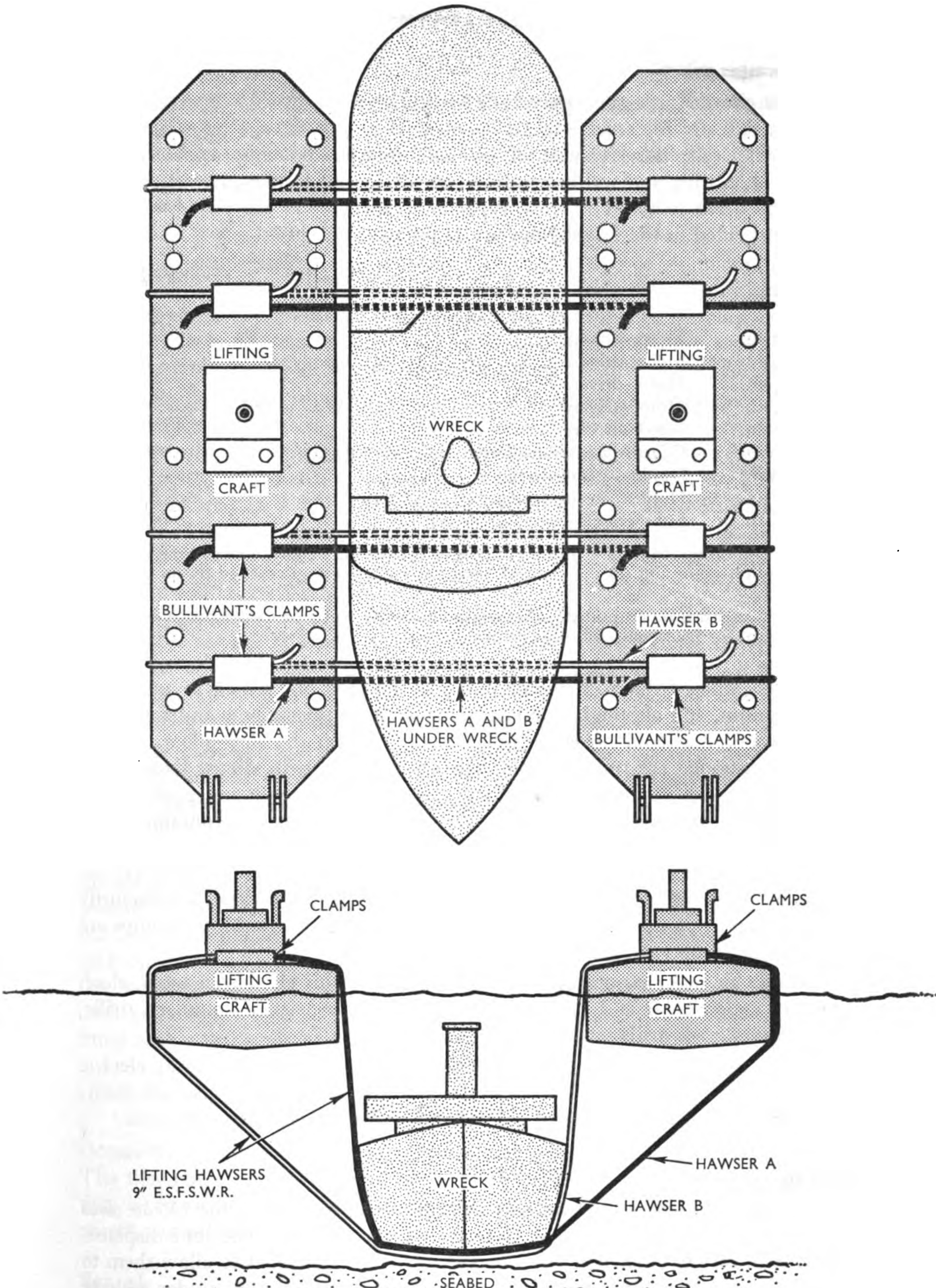


Fig. 7–13. Method of securing lifting hawsers round a wreck from a pair of lifting craft

Salvage plant

Stocks of the necessary plant and equipment for salvage operations are maintained ready for service at all boom-defence and salvage bases and most naval dockyards; these consist of portable pumps, air-compressors, electric generators, cutting and welding equipment, diving equipment, hawsers, blocks and many other items. The sizes, types and capacities of the portable salvage pumps provided in the Royal Navy are as follows:

Size	Type	Capacity in tons per hour	Combined head* in feet
12-in.	Motor-driven	750	40
8-in.	Motor-driven	400	40
6-in.	Motor-driven	200	40
4-in.	Motor-driven	120	40
3-in.	Motor-driven	30	40
8-in.	Centrifugal, steam-driven	350	40
6-in.	Duplex, steam-driven	75	40
3-in.	Duplex, steam-driven	25	60
$2\frac{1}{2}$-in.	Submersible sump, air-driven	31	40 (actual†)

* The 'combined head' of a pump is the sum of: (*a*) the height of the pump above its lowest suction-point and (*b*) the greatest height above the pump reached by its discharge pipe.

† The 'actual head' of a pump is the height above the pump of its discharge point, less an allowance for frictional and other losses.

Of these pumps the 3-in. motor-pump is the only one which is not a true salvage pump, and although it is handy for small compartments and for transferring water it should never be relied upon to keep the ship afloat. All the pumps mentioned are transportable, and are supplied with slings. Each pump has the necessary suction and discharge pipes, spares, tools and gear and an initial supply of consumable stores. Most of these items are contained in a spare-gear box which is easily transportable. Steam pumps are the most reliable for use on salvage work, but have the disadvantage of the difficulty often experienced in obtaining steam; 6-in. and 3-in. steam pumps function satisfactorily when driven by compressed air, but usually at reduced power. Motor pumps are handy because they require only fuel and oil.

Portable air compressors are supplied complete with air-driven tools which function under water and are used by divers; they consist of hammers, drills, wood borers, rock drills, etc.

Underwater cutting equipment (both oxy-hydrogen and oxy-electric), electric underwater welding gear and above-water burning and welding gear are maintained, together with supplies of gas and the necessary electric generators.

Salvage vessels

There are two types of Admiralty salvage vessel in service, the *Ocean* class and the *Coastal* class. The *Ocean* class are vessels of about 1,680 tons displacement, twin-screw, of shallow draft and specially strengthened to allow them to be grounded. They are designed for offshore salvage operations under adverse weather conditions and are fitted for firefighting. They have a maximum speed of 12 knots and an endurance of 4,500 miles at their economical speed of eight

knots. In addition to the ship's normal auxiliaries, a 14-in. salvage pump, an air compressor and a fire pump are fitted in the engine room. The salvage pump has an output of 1,000 tons per hour at a combined head of 40 ft. Fixed suction pipes lead forward and aft to manifolds on deck, and each manifold is fitted with six 6-in. flexible suction pipes which are passed into the ship being salvaged. The pump is fitted with a sea-suction and can be used for flooding back if required.

The air compressor has an output of 340 cu. ft of free air per minute at a pressure of 100 lb per sq. in. An air main runs fore-and-aft below the upper deck from the air reservoir to valves and connections throughout the ship above and below decks. Full sets of air-driven tools and equipment are provided, and suitable manifolds for supplying air to the wreck are fitted on deck.

The firefighting equipment includes two 4-in. *monitors* situated abaft the funnel on the upper deck, three 2½-in. hose-manifolds each with six connections, 16 ordinary branch-pipes, two monitor-type branch-pipes and ten foam-making branch-pipes, 16 variable-spray nozzles, and 24 one-inch nozzles. Foam compound is stored in a 1,000-gallon tank in the engine room. In addition, 45 cylinders of liquid CO_2 with a full range of hoses, adaptors, manifolds, etc. are included, together with three portable units, each of two cylinders, mounted on trolleys.

The ships are provided with a well-equipped workshop and large quantities of portable salvage equipment with the necessary stores. Extra heavy anchors and cables are carried, and powerful capstans with heavy deck-clench plates and fittings are provided to enable the ships to haul off stranded vessels. In fact, they are virtually fully-equipped and mobile salvage bases.

Coastal class salvage vessels are single-screw ships, specially designed and primarily intended for harbour clearance and shallow-water salvage work. They are heavily built to take the ground and can steam with a great load slung from their bows. Their approximate displacement is 1,068 tons, with a speed of nine knots and an operating radius of nearly 2,000 miles under normal conditions, but this can be increased to 3,500 miles by carrying additional fuel in reserve bunkers. In common with the *Ocean* class they are fitted for firefighting, but not on such a lavish scale. Twin lifting-horns which overhang the stem are each capable of a lift of up to 50 tons, and lifts of up to 200 tons can be taken over the bows by means of two six-fold purchases rigged on the fore deck. Heavy deck-bollards are fitted, and side lifts can also be taken. These vessels are also fitted with a workshop and carry a good outfit of salvage equipment and stores.

SALVAGE OF CRASHED AIRCRAFT

Occasions arise when it is necessary to search for, locate and salvage an aircraft. The first point to consider will be whether the information and material that may be recovered can justify the cost of ships, men and material during the search and salvage operation.

Search

If the expenditure is justified the search can be organised. Most aircraft that crash at sea are either sighted by ships, manage to transmit their position, or

are heard to transmit by W/T or R/T for a period sufficient for a ship or shore station to obtain a bearing of their transmission. This position is a very rough datum, or starting-point of the search, but it will assist in planning the search area.

There are a number of methods which can be used when trying to locate an object on the sea bed. Civilian trawlers can be chartered to trawl, if the sea bed is suitable for trawling. Pairs of ships using a wire sweep are effective, but the wire sweep may damage the aircraft if and when the wire fouls it. Underwater television and observation-chamber diving, when the visibility is good, have both proved successful for identification, but undoubtedly the best method of location is to use vessels fitted with electronic equipment. Such equipment, after locating the aircraft, can also be used either to direct a diver to the aircraft or a salvage vessel to the exact point above it.

Use of divers

If possible, it is always better to get a diver down to secure a wire or wires around the strongest section of the aircraft than to attempt to use a grab or the fouled wire of a wire sweep. The use of divers will be restricted when operating in adverse weather conditions, tidal waters, bad visibility or great depths. However, the use of divers should keep damage to the aircraft during its salvage to a minimum.

After a suitable wire has been secured, the salvage vessel first plumbs the aircraft and then heaves in the wire at slow speed. Before the aircraft is hoisted clear of the water additional wires should be passed around it to act either as preventers or as bowsing-in lines.

CHAPTER 8

Moorings

Permanent moorings may be laid for the following purposes:

1. to make the most of the usually limited space of a harbour anchorage;
2. to berth ships as near as possible to the landing-places so as to facilitate embarking and disembarking stores, cargo, crew or passengers;
3. to provide secure moorings for ships in crowded waters, especially for those laid up and others unable to move under their own power;
4. to ensure that ships are berthed exactly, and in the most suitable positions for each other's safety and for the preservation of lanes for harbour traffic;
5. to reduce the possibility of ships dragging in heavy weather. (A ship is usually more secure at a permanent swinging mooring than at anchor.)

The two main types of permanent mooring are the *swinging mooring*, where a ship secures head to a buoy and is free to swing to the wind and tidal stream; and the *head-and-stern mooring*, where a ship secures head-and-stern between two buoys. Swinging moorings are always laid if space permits, because ships can make fast to them and slip from them with the minimum of help. Where space is limited, however, ships must be secured to head-and-stern moorings, which have the following disadvantages:

1. A ship usually requires tugs when securing to them and slipping from them, particularly when the wind is athwart the line of moor.
2. When a ship is secured to them in a strong beam wind they are subjected to a very great load and so they have to be particularly strong and secure.
3. A mooring intended for a long ship is not suitable for a short ship.

Remarks on how to handle ships while securing to head buoys, or head-and-stern between two buoys, are given in Chapter 13 (pages 295–301).

PARTS OF A MOORING

The three main parts of a mooring comprise the *ground tackle*, the *buoy pendant* and the *buoy*. These are shown in fig. 8–1.

Ground tackle

This consists of one or more mooring anchors, with a *ground arm* of mooring chain shackled to each and led to a *central mooring ring*, to which is shackled the *buoy pendant*.

Mooring anchors (fig. 8–2). These are usually stocked, single-fluke anchors, and they are usually heavier than the bower anchors of the ships for which the mooring is designed. They are carefully placed and embedded to ensure that the mooring and its buoy are in the correct position. Because they are seldom dropped and embedded by dragging like a ship's anchor they have only one fluke, and a stock is incorporated to prevent the anchor from rolling out of its

bed. A small explosive charge may be used to dig a hole for the fluke of a mooring anchor when the harbour bottom is unusually hard. Mushroom anchors or clumps are sometimes used instead of fluked anchors for single moorings. Details of Admiralty mooring anchors are given in Table 8–3, on page 185.

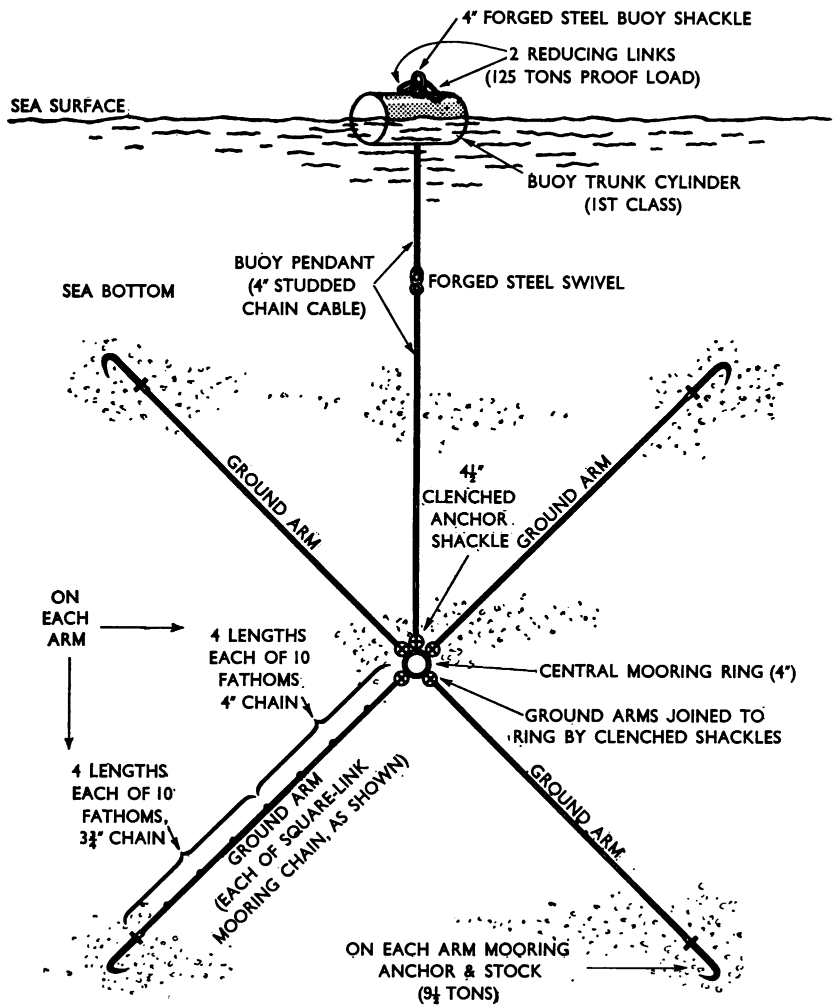
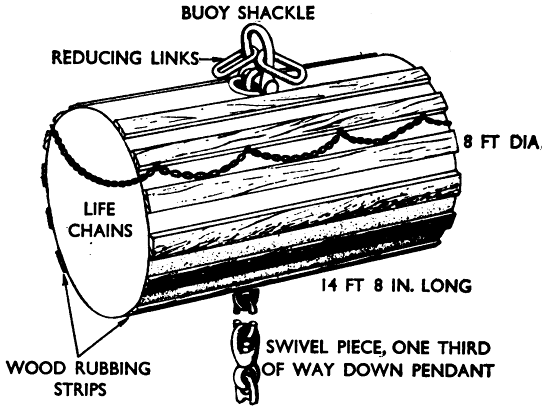
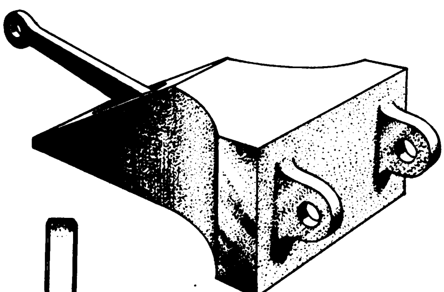


FIG. 8–1. Diagrammatic sketch of mooring, showing principal parts. A four-arm first-class mooring (1946 standard) is shown. It is used for ships with cable up to $3\frac{1}{16}$-inch steel or $4\frac{1}{4}$-inch iron. The total weight of ground chain and anchors is $205\frac{1}{2}$ tons

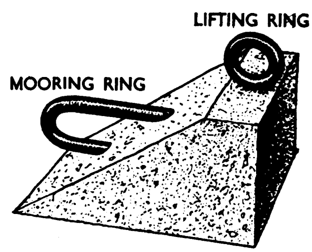
A ship's stockless anchor is not suitable as a mooring anchor unless its flukes are wedged at the full angle of their travel and it is provided with a stock of about the same length as the shank and fitted just below the ring. The anchor must then be laid flukes downward and embedded by dragging.



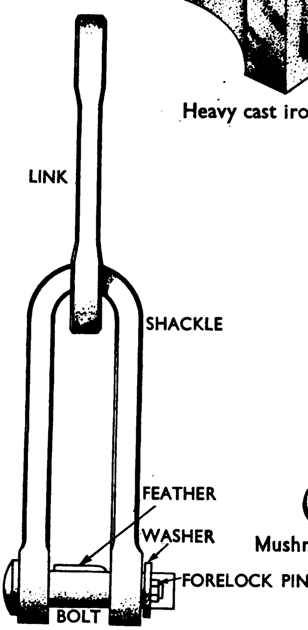
Cylindrical steel mooring buoy, 1st class



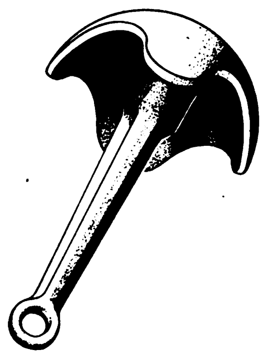
Heavy cast iron clump



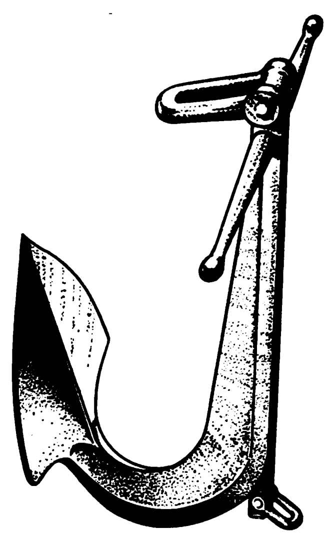
Small ferro-concrete clump



Square-link and forelock mooring shackle



Mushroom anchor



Mooring anchor A.M.12.

FIG. 8–2. Mooring buoy and types of ground tackle for moorings

Ferro-concrete or cast-iron clumps are sometimes used in minor moorings instead of anchors (fig. 8–2). These clumps give good holding pull in a soft, muddy bottom, but hard ground should be loosened for them by grab dredging. They are used in shallow water, and may lose approximately 40 per cent of their weight when submerged because of buoyancy.

Arms of ground tackle. These are made up usually of lengths of special *square-link* mooring chain, composed of long, square-section links, the lengths being joined by a special *forelock mooring shackle* (fig. 8–2). *Clenched* mooring shackles are used where the inner ends of the arms are shackled to the central mooring ring, because movement is likely to occur there. These shackles have to be clenched before the mooring is laid.

Buoy pendants

These are made up from lengths of ordinary studded chain cable. Pendants are usually fitted with a swivel, even in a head-and-stern mooring, because then the buoys can always be used as swinging moorings if necessary. The swivel is inserted by means of manufactured links at one-third of the length of the pendant from its upper end.

The lower end of the buoy pendant of the heavier moorings is made up of end links of cable, usually of a size larger than the rest of the pendant to allow for the excessive wear caused by the rise and fall of the tide. The length of the part of the pendant thus reinforced is equal to the maximum range of the tides. The pendant is secured to the mooring ring by a clenched anchor shackle (fig. 8–1).

The length of a buoy pendant or a bridle is decided by the depth of water at H.W. springs, and also by the required freeboard of the buoy when it is supporting the pendant; to this is added a length of spare slack, usually one fathom or as decided by the mooring officer.

Buoys

Mooring buoys. All modern Admiralty mooring buoys are built on the trunk principle and are cylindrical in shape (fig. 8–2). The larger ones are divided into watertight compartments by longitudinal and transverse bulkheads. The buoy pendant is led up through a central trunk in the buoy, and the bolt of the buoy shackle is passed through the end link of the buoy pendant. The ship's cable is shackled directly to the buoy shackle, or to a reducing link on the shackle if the mooring is designed for a heavier type of ship.

The size of a buoy depends on the size and length of the pendant which it supports, and also on the reserve of buoyancy which the buoy is required to have. For the higher classes a reserve of buoyancy of 35 per cent is usually allowed, but this may be reduced to a minimum of 25 per cent if necessary; for the lower classes the corresponding reserves of buoyancy are 20 per cent and 15 per cent. There are six classes of mooring buoys which correspond generally with the six classes of moorings, but in deep water a buoy may be of a higher classification than its mooring because it has to support a long buoy pendant. Table 8–2, at the end of this chapter, shows the various classes of mooring buoy and the size and maximum length of pendant with which each is designed to be used in normal circumstances. Moorings, except those of the highest class

can be laid in greater depths than those indicated in the table if a buoy of sufficient size is provided to support the pendant.

Mark buoys. Floating temporary marks are required for many purposes—for example:

1. to mark ranges for target practice,
2. to indicate the limits of a minefield when laying or clearing mines,
3. to mark the course for a regatta,
4. to mark shoals, rocks and channels when surveying.

When possible, a mark buoy should be moored to a clump or to a stockless anchor, and not to an Admiralty-pattern anchor, because when sweeping round with the wind or tide its pendant is almost certain to foul the upper fluke of an Admiralty-pattern anchor and possibly trip it so that both anchor and buoy will drift away.

Small casks, pieces of wood, or spars may be used as mark buoys, and they answer fairly well where there is little wind or tidal stream; but if the mark or its flag is to be seen from a distance when a fresh breeze is blowing or a strong current running, something more stable is required. In the Royal Navy two types of mark buoy are provided, namely, the *dan buoy*, which is described in Volume I, and the *standard surveying beacon* (fig. 8–3), which can carry a far taller and more conspicuous mark than the dan buoy.

A suitable mooring for a standard surveying beacon is shown also in figs. 8–3 and 8–4. The wire pendant should be adjusted so that the total length of the buoy pendant will be about one-third more than the greatest depth of water at the position in which it is proposed to lay the buoy, thus allowing for the effects of any tide, tidal stream or current. The buoy is designed to support (with 14 per cent reserve buoyancy) $4\frac{1}{4}$ cwt, or 15 fathoms of $\frac{3}{4}$-in. chain, and the pendant should not exceed this weight.

TYPES OF MOORINGS

Single-clump mooring

The simplest form of mooring (fig. 8–5) consists of a buoy, buoy pendant and clump anchor. It is generally used for mark-buoys and for small craft such as harbour launches and lighters. The consequences of slight dragging are not serious, because the weight of the clump will help to rebed it, and it is easily returned to its position.

Span mooring

The heavier types of swinging moorings may be of the span type, each of the two main arms being provided with two anchors (fig. 8–6 (i)). The disadvantage of this mooring is its tendency to drag when the wind is across the stream, and the consequences of a large ship dragging are, of course, serious.

Two-arm mooring

The lighter swinging moorings in restricted waterways may be of the two-arm type (fig. 8–6 (ii)), one anchor being laid on the end of an arm of mooring chain upstream, and another on a similar arm downstream. The disadvantage of this

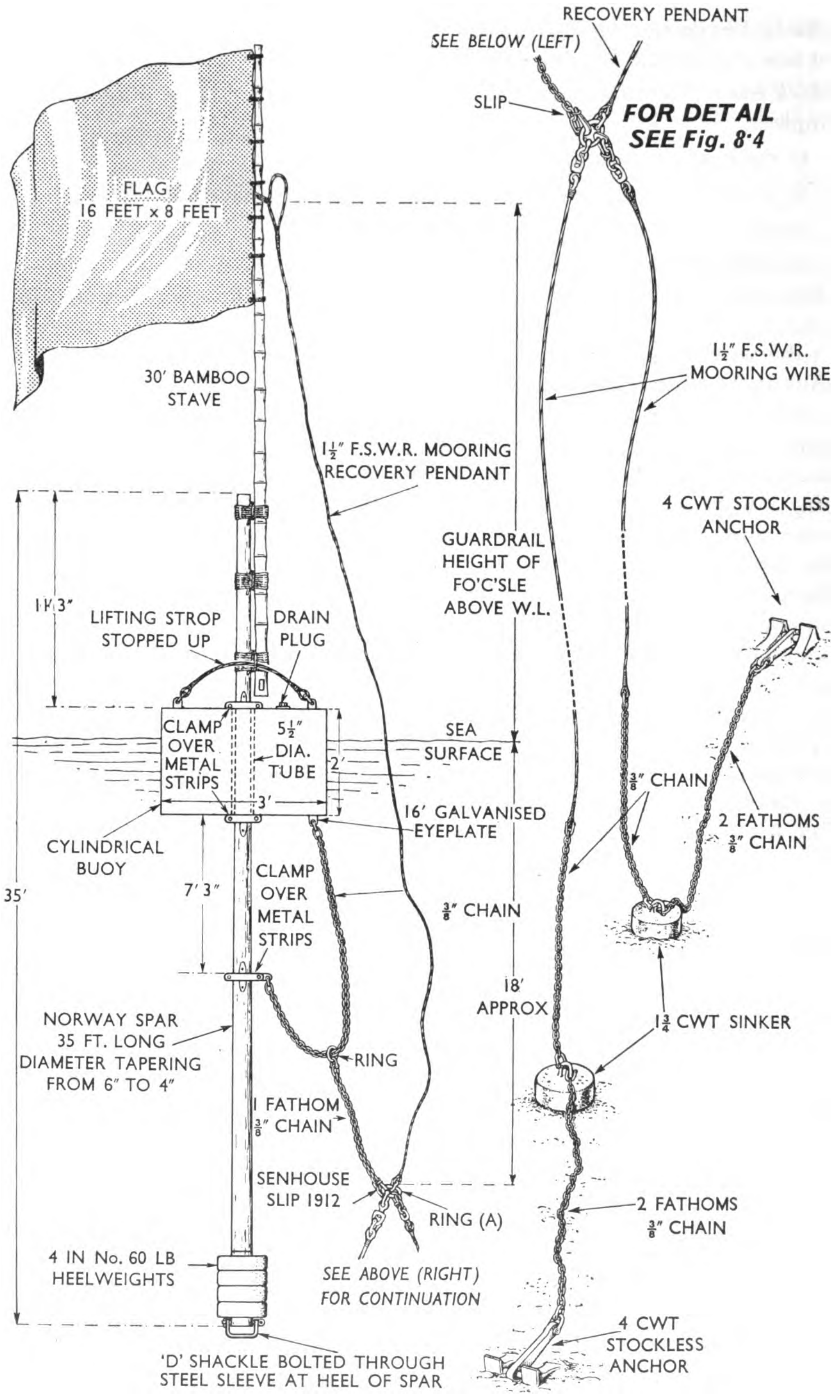


FIG. 8–3. Standard surveying beacon (*left*) and its mooring (*right*). The lengths of the mooring wire used depend on the depth

mooring is also its lack of resistance to dragging when the wind is across the stream, and to return it to its original position when once it has dragged is a major operation.

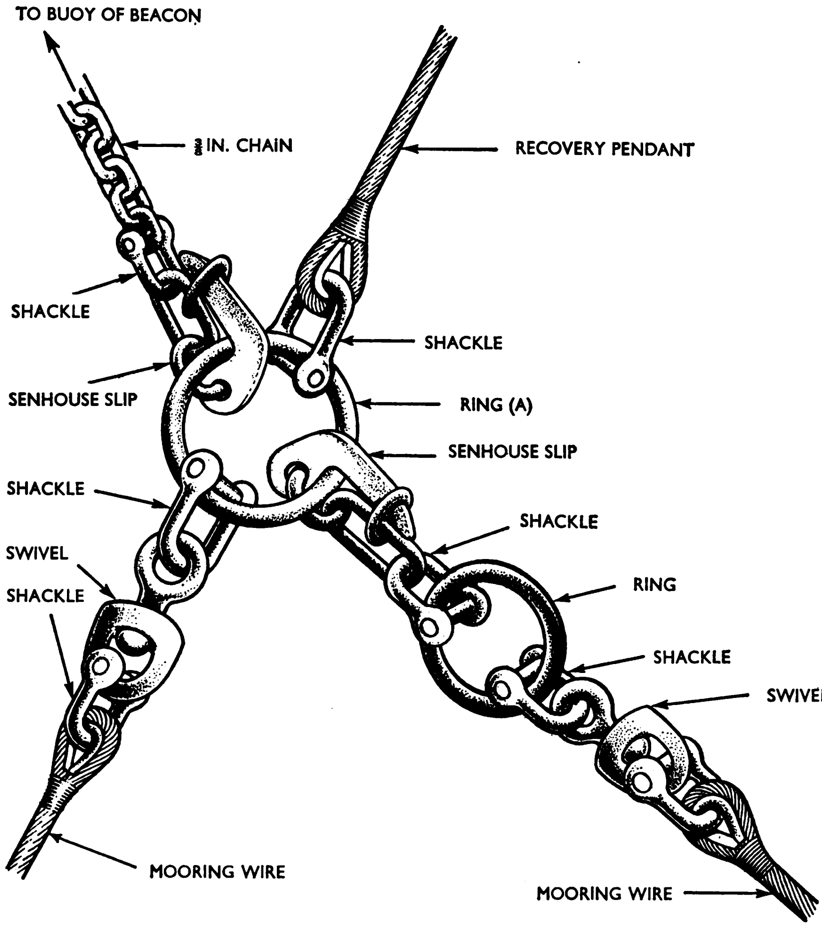


FIG. 8–4. Detail of method of securing standard surveying beacon and recovery pendant to mooring wires of its anchors (see fig. 8–3)

Three-arm mooring

This swinging mooring (fig. 8–6 (iii)) is most satisfactory from the point of view of security, and it is used generally for the heavier types of swinging moorings. Its resistance to dragging is nearly constant with the wind from any point of the compass, but it occupies a wider area than the span and the two-arm moorings.

Four-arm mooring

This swinging mooring is used for the heaviest types of ships (figs. 8–1 and 8–6 (iv)). It has all the advantages of the three-arm mooring, but its four arms provide greater security.

Screw type mooring

This swinging mooring is used largely in commercial ports and rivers (fig. 8-6 (v)). It is very economical in material, but is only suitable for harbours with fairly hard bottoms in which it holds well. Its great disadvantage is that if the screws draw they entirely fail to hold, as they have little deadweight and cannot regain hold. For this reason screw type moorings are not used in Naval ports.

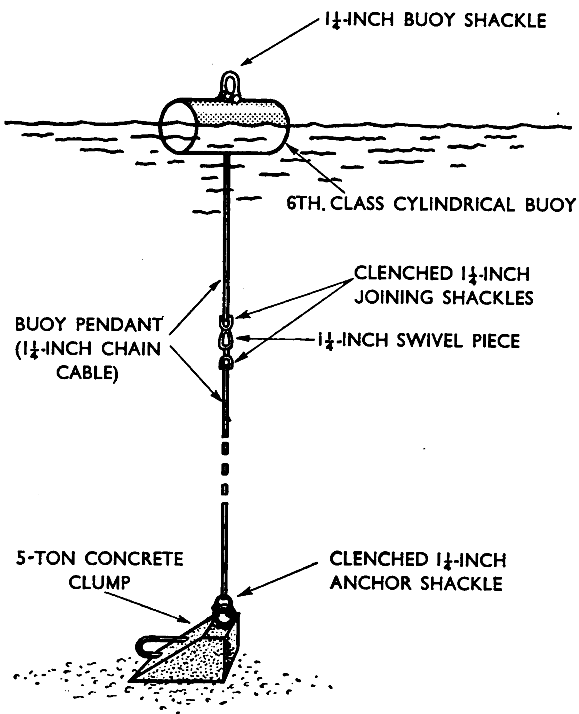


FIG. 8–5. Single mooring—a typical single clump mooring for small craft, lighters, etc.

Trot mooring

This type of mooring is laid for securing numbers of frigates or smaller vessels in line, head to stern, and is economical of space and material (fig. 8–6 (vi)).

Head-and-stern mooring

The type of mooring shown in fig. 8–6 (vii) is that generally used for mooring a ship head and stern. Each of its component parts is at least of the same size or weight as those of a corresponding swinging mooring.

Bridle type, four-arm mooring

This is the most secure type of head-and-stern mooring, but it is very cumbersome and is therefore only used for mooring ships which are laid up permanently, such as hulks and training ships. The four bridles are led inboard through hawse-pipes on each bow and quarter of the ship (fig. 8–6 (viii)).

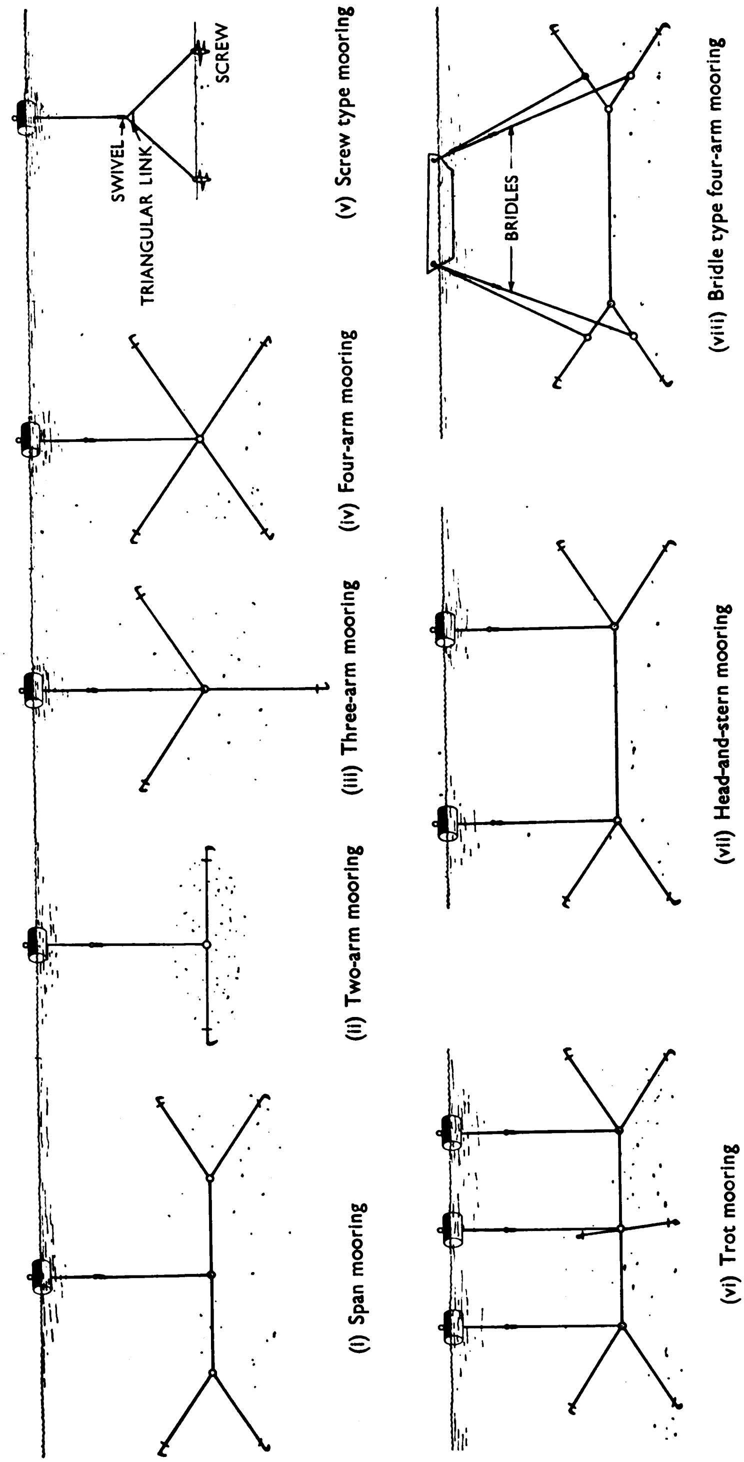


FIG. 8-6. Types of moorings for ships

CLASSIFICATION OF MOORINGS

Because of the great differences in length and displacement of ships several classes of moorings must be provided. Moorings are classified according to the size of the cable of the ships which may safely use them; generally speaking, *first-class* moorings are suitable for aircraft carriers, *second-class* for cruisers and large auxiliaries, *third-class* for guided-missile destroyers and small auxiliaries, *fourth-class* for destroyers and frigates, and *fifth-* and *sixth-classes* for other smaller ships and craft, such as minesweepers.

A ship should not secure to a lighter class of mooring than that designed for her, but cruisers and smaller ships may use heavier swinging moorings than those specified for them, and also heavier head-and-stern moorings if the length between the head and stern buoys is not too great. For this purpose one or two special *reducing links* are fitted to each buoy shackle of the heavier moorings to enable the securing-to-buoy shackle of a smaller ship to be joined to the buoy. These reducing links, however, must never be used by the class of ship for which the mooring is designed. A ship is usually allowed to secure her cable to a buoy if its pendant has a certain specified margin of strength over that of the ship's cable.

Table 8–2, at the end of this chapter, gives a list of the different classes of moorings, together with the size of ship's cable for which each class of mooring is suitable. The size of cable should always be the standard used when deciding whether a mooring is suitable for a particular ship, because it takes into account the maximum stresses involved at all states of loading, these usually being highest when the ship is at light-load draught owing to the large windage area she then presents.

In the last column of the table is given the displacement of the largest ship for which each class of mooring is suitable. In determining the number of small craft which may lie abreast at any mooring, the aggregate proof load of the several cables should be the deciding factor. In sheltered waters, the number of ships permitted to lie abreast in a head-and-stern mooring may be calculated on a displacement basis, by adding to the displacement of the largest ship one-half the displacement of each of the other ships. This rule is to be applied at the discretion of mooring officers, who should bear in mind that, at reduced displacements, ships present increased windage area. Cable-diameter classification of moorings is more reliable than displacement classification, because the cable diameter of a ship is selected with due regard to the windage area.

HOLDING POWER OF MOORINGS

The forces acting on a ship riding at a mooring are:

1. a steady force caused by tidal current acting on the underwater hull,
2. the wind force on the above-water surface, which may be steady or fluctuating according as the wind is steady or squally,
3. the sudden snatch loads on the cable caused by the motion of the ship in waves.

The following table gives estimated values of pulls which ships may exert on their moorings when acted upon by a 60-knot steady wind and a 5-knot tidal

stream. It has been assumed that the tide and wind act fore-and-aft along the ship in each case. This information will give some idea of the holding power required in a mooring. It should be noted that the wind and tidal forces are approximately proportional to the square of the speed in each case, and further values can therefore be deduced as necessary for the speeds.

Type of ship	Ahead wind resistance. Wind speed 60 knots	Ahead tide resistance. Tidal speed 5 knots	
		Hull	Locked propellers
	tons	*tons*	*tons*
Aircraft Carrier (43,000 tons)	31	12	14
Cruiser (12,000 tons)	13	6	8
Cruiser or Guided-missile Destroyer (5,000 tons)	10	4	6
Frigate (2,000 tons)	6	3	2

It will be seen from the table that when the current is exceptionally strong it is advisable to trail the propellers.

It should be noted that if the 60-knot wind included gusts of up to 85 knots, the maximum transient wind force on the ship would be approximately double the values quoted. It is then that any extra cable laid out plays an important part by absorbing these shock pulls.

Mooring anchors must be well buried in the sea bed if they are to be effective, and the length of the ground arms must be sufficient to ensure that the pull on the anchor will be horizontal in all conditions of service, otherwise the mooring may drag.

The holding pull of an anchor depends, to a large extent, on its weight, the area of the flukes and the moment of this area about the surface of the sea bed. It is only possible to get a high holding pull by forcing the anchor to penetrate deeply into the sea bed. The provision of an anchor which is capable of this has been the object of much research in recent years. The result has been the introduction of the Admiralty Mooring Type 12 (A.M.12) anchor (fig. 8–2). This anchor will withstand a horizontal pull of 14 times its own weight, and the whole anchor will penetrate the sea bed after being pulled horizontally a distance of only one shank-length.

In the permanent mooring anchor with a fixed fluke and stabilising stock, it is possible to arrange the fluke below the shank, and separated from it by a certain optimum distance. In this way the fluke digs into the subsoil and develops sufficient pull to drag the shank in also. Consequently, the whole of the anchor contributes towards the holding pull rather than just the fluke, as in earlier designs. The provision of a stock prevents the anchor turning over under heavy load.

The larger the anchor the more strongly must it be constructed to withstand the stresses to which it may be subjected. The approximate holding powers in reasonably good holding ground of mooring anchors in terms of their weights are given in Table 8–3, on page 185. It should be realised that the weight of the mooring chain on the seabed also contributes to the holding power of the mooring.

MAINTENANCE OF MOORINGS

Moorings exposed to strong tidal streams and rough weather naturally suffer more wear and tear than those in tideless sheltered waters. Corrosion, however, particularly in estuaries and in tropical harbours, can cause as much reduction in the weight of the cables as does the wear and tear caused by tidal streams and weather. For this reason moorings at dockyards and bases abroad are usually overhauled at more frequent intervals than those at home.

Moorings at home dockyards are *examined* annually and *surveyed* at intervals of from two to five years, the interval depending on the class of mooring, the lighter moorings being surveyed more frequently than the heavier moorings. A survey entails raising the entire mooring and usually landing it for thorough overhaul and repair; whereas an examination is carried out on the spot without disturbing the anchors. The annual examination consists of the inspection and maintenance of above-water components, i.e. buoy, buoy shackle, reducing links, and slack in the upper part of the pendant.

An inspection by a diver of the pendant and mooring components around the mooring ring is carried out at least one year before the periodic survey. This is to enable the mooring officer to order any new materials that might be required during the periodic survey. At home dockyards the intervals at which the various classes of mooring are surveyed are as follows:

First- and second-class moorings—every five years; first-class moorings which have, however, been frequently used by ships equipped with chain cable larger than 3-inch wrought iron or the equivalent size in forged steel are surveyed every three years.

Third-class moorings—every three years.

Remaining classes of moorings—every two years.

MISCELLANEOUS MOORINGS

Swamping a mooring

In an open anchorage which is frequently exposed to the full force of gales and heavy seas, or in one that is subject to a heavy prevailing swell, the buoy of a swinging mooring will not withstand the excessive wear and tear imposed on it. To overcome this difficulty the mooring buoy is removed entirely, and when not occupied the mooring is *swamped* by veering its buoy pendant to the bottom on a composite recovery pendant made of wire rope and chain cable, to which a small but robust buoy is attached by a light buoy pendant. The chain cable is of the appropriate ship's-cable size for the class of mooring (see Table 8–1). When the mooring is swamped both the heavy buoy pendant and its recovery pendant lie on the bottom, with the small buoy watching over them.

Although the weight of the recovery pendant will tend to keep the buoy in position, it must not be assumed that it will always watch over the centre of the mooring. The position of the mooring should therefore be fixed accurately by bearings—or, better still, by transits of marks on shore—to enable a ship when picking up the mooring to place her bows over its centre and so reduce the strain on the recovery pendant as the heavy buoy pendant is hove up from the bottom.

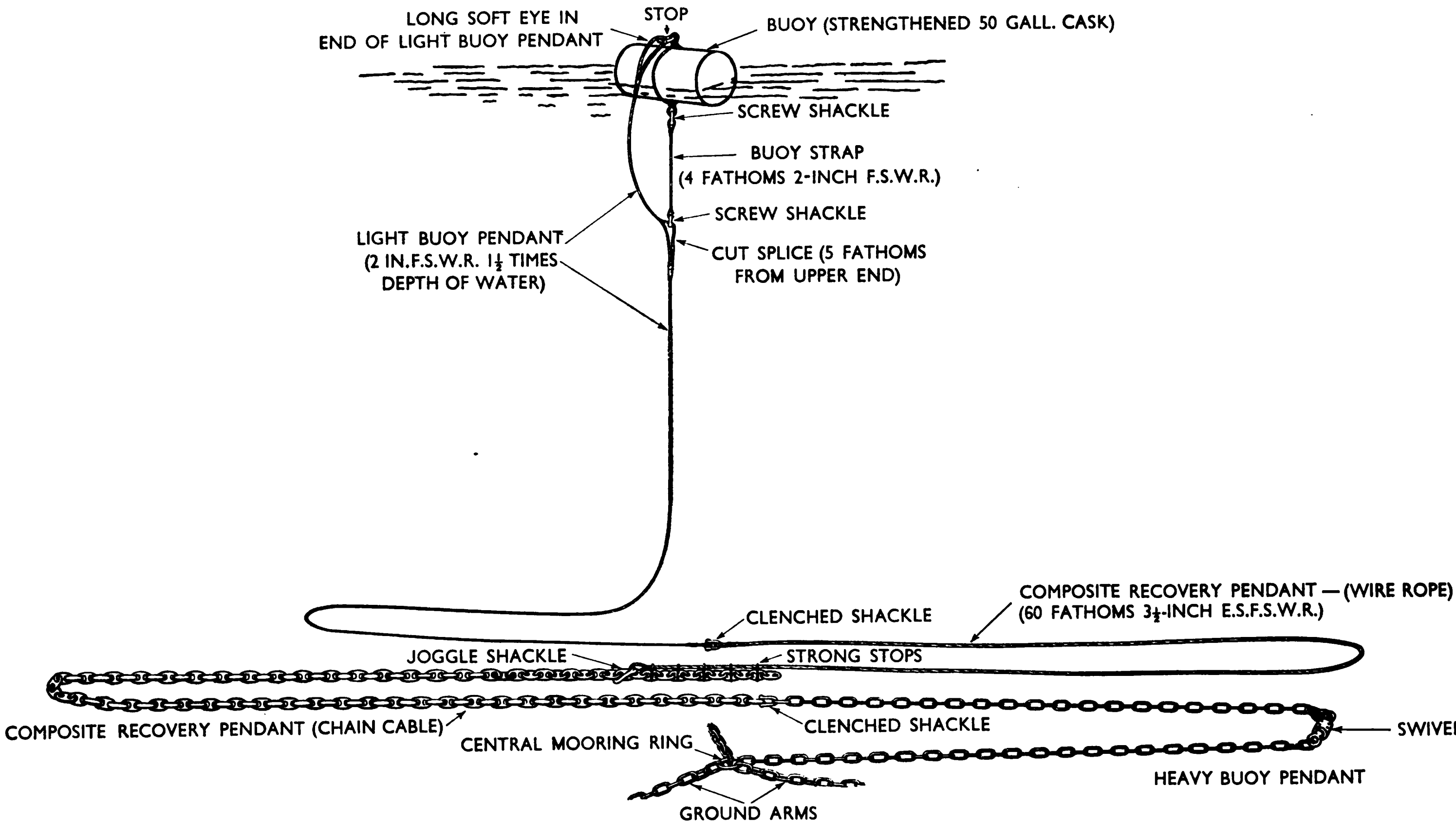


FIG. 8–7. A typical swinging mooring fitted for swamping

It might also be necessary to swamp a mooring temporarily in order to give greater swinging room at an adjacent mooring. Whenever a mooring is swamped, it is essential to make adequate arrangements for its recovery, either by a small buoy, as already mentioned; or by leading the recovery pendant to an adjacent mooring buoy and securing it below the swivel in the buoy pendant; or by leading it to the nearest point ashore, if reasonably close.

A typical swinging mooring fitted for swamping is shown in fig. 8–7.

Telephone cables at moorings

Certain mooring berths in a port may be provided with telephone or teleprinter cables. For head-and-stern moorings the telephone cables are led from the shore along the bottom, clear of the ground arms, to a separate buoy which is secured to one of the mooring buoys, sufficient scope being allowed in the cables for the tidal range. The ship's telephone cables are then joined to the shore telephone cables on this buoy.

The provision of telephone cables for a swinging mooring is more complicated, however, because the cables are liable to foul the buoy pendant as the ship swings round the buoy. In some ports this difficulty is overcome by mooring the buoy with a two-legged (or four-legged) bridle to its ground arms, as shown in fig. 8–8, thus preventing the buoy from rotating. The ship's bridle is then shackled to a *spectacle-lug* which revolves around a collar fitted to the upper end of the buoy-trunk. The shore telephone cable is led up through the buoy trunk and is thus clear of the mooring, and the ship's telephone cable is led along a jury sprit of sufficient length to keep it clear of the bridle while plumbing the buoy. The connection between ship and shore telephone cable is made by a swivelling *slip-ring*. Where provision is not made at a swinging mooring to prevent a telephone cable from fouling the mooring, a watch must be set to keep it clear as the ship swings.

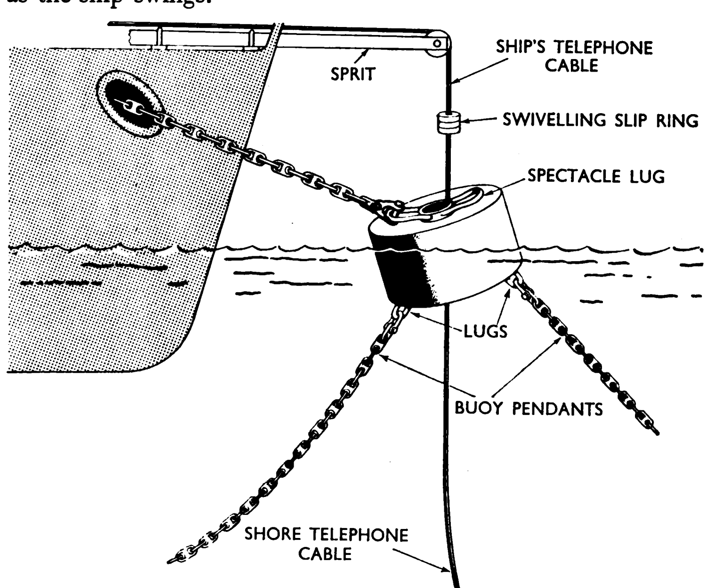


FIG. 8–8. A special type of telephone mooring buoy

Hauling-off moorings

Hauling-off moorings are usually provided in a harbour which is subject to scend, for holding a ship clear of a jetty against her berthing hawsers. If the weather deteriorates and the ship is in danger of bumping heavily against the jetty or catamarans, the ship's officers should have her hauled off clear with the off-fasts until the wind moderates.

In ports where a strong prevailing wind blows directly on to the berthing jetties, hauling-off buoys, to which hawsers may be secured, are sometimes provided to enable ships to haul themselves well clear of the jetty against the wind when unberthing.

TABLE 8–1
CLASSES OF MOORINGS

Class of Mooring	Classification by Size of Ship's Cable							Classification by Displacement
	Sizes of Buoy Pendant*			Sizes of Ship's Cable for which each Class of Mooring is Suitable				
				Wrought-Iron Cable		Forged-Steel Cable		
	Diameter when new	Diameter when worn to min. size allowable	Proof load for worn size	Diameter	Proof load	Diameter	Proof load	
	in.	*in.*	*ton*	*in.*	*ton*	*in.*	*ton*	*ton*
1st (1946)	4 (steel)	$3\frac{1}{2}$	247·0	$4\frac{1}{4}$	206·0	$3\frac{1}{16}$	209·7	50,000
1st (1922) (swinging or head & stern)	4 (iron)	$3\frac{3}{4}$	189·8	$3\frac{3}{8}$	169·1	$2\frac{7}{8}$	192·6	40,000
1st (1916)	4 (iron)	$3\frac{5}{8}$	182·0	3	145·8	$2\frac{5}{8}$	170	35,000
1st (1916) (light)	4 (iron)	$3\frac{1}{2}$	176·4	$2\frac{15}{16}$	141·7	$2\frac{1}{2}$	157·5	25,000
2nd	$3\frac{1}{2}$ (iron)	$3\frac{1}{16}$	149·8	$2\frac{9}{16}$	116·7	$2\frac{1}{4}$	127·6	16,000
3rd (3-arm)	3 (iron)	$2\frac{5}{8}$	120·9	$2\frac{5}{16}$	96·3	2	100·8	7,000
3rd (2-arm)	$2\frac{3}{4}$ (iron)	$2\frac{7}{16}$	106·9	$2\frac{1}{8}$	81·3	$1\frac{7}{8}$	88·6	6,000
4th (3-arm)	$2\frac{9}{16}$ (iron)	$2\frac{1}{4}$	91·1	2	72·0	$1\frac{3}{4}$	77·2	3,000
4th (1934)	$2\frac{9}{16}$ (iron)	$2\frac{1}{4}$	91·1	2	72·0	$1\frac{3}{4}$	77·2	2,500
4th	$2\frac{1}{4}$ (iron)	2	72·0	$1\frac{3}{4}$	55·13	$1\frac{1}{2}$	56·8	2,000
5th	$1\frac{5}{8}$ (iron)	$1\frac{7}{16}$	37·1	$1\frac{1}{4}$	28·13	$1\frac{1}{8}$	31·9	600
6th	$1\frac{1}{4}$ (iron)	$1\frac{1}{8}$	22·75	—	—	—	—	400

* All pendants are of wrought iron except 1st Class (1946), which is of forged steel.

Note: The dates shown in the first column indicate the year in which these moorings were standardised, and provide a means of distinguishing one mooring from another of the same class.

TABLE 8–2. PENDANTS FOR MOORING-BUOYS

BUOY (CYLINDRICAL)			MOORING CLASS	PENDANTS FOR 35% RESERVE BUOYANCY	PENDANTS FOR 25% RESERVE BUOYANCY
CLASS	LENGTH	DIAMETER			
	ft in.	*ft in.*			
Monster 1st 4 compartments	16 0	8 0	1st	9 fm. 4½ in. c.c.+4½ fm. 5 in. end links	12 fm. 4½ in. c.c.+6 fm. 5 in. end links
			1st	13 fm. 4 in. c.c.+4 fm. 4½ in. end links	20 fm. 4 in. c.c.+4 fm. 4½ in. end links
1st 4 compartments	14 8	8 0	1st	10 fm. 4 in. c.c.+4 fm. 4½ in. end links	15½ fm. 4 in. c.c.+4 fm. 4½ in. end links
			1st	12 fm. 4 in. c.c.+4 fm. 4 in. end links	17 fm. 4 in. c.c.+4 fm. 4 in. end links
			*2nd	16 fm. 3½ in. c.c.+6 fm. 3½ in. end links	23 fm. 3½ in. c.c.+6 fm. 3½ in. end links
2nd 4 compartments	13 2	7 6	2nd	11 fm. 3½ in. c.c.+5½ fm. 3½ in. end links	14½ fm. 3½ in. c.c.+7 fm. 3½ in. end links
			3rd	18 fm. 3 in. c.c.+6 fm. 3 in. end links	22 fm. 3 in. c.c.+7 fm. 3 in. end links
			*3rd	21 fm. 2¾ in. c.c.+6 fm. 2¾ in. end links	29 fm. 2¾ in. c.c.+6 fm. 2¾ in. end links
3rd 4 compartments	11 6	6 6	3rd	8 fm. 3 in. c.c.+4 fm. 3 in. end links	10 fm. 3 in. c.c.+5 fm. 3 in. end links
			3rd	9½ fm. 2¾ in. c.c.+5 fm. 2¾ in. end links	13 fm. 2¾ in. c.c.+6½ fm. 2¾ in. end links
			*4th	19 fm. $2\frac{9}{16}$ in. c.c. No end links	26 fm. $2\frac{9}{16}$ in. c.c. No end links
			*4th	22½ fm. 2¼ in. c.c. No end links	31 fm. 2¼ in. c.c. No end links
4th 4 compartments	9 6	5 6	4th	8½ fm. $2\frac{9}{16}$ in. c.c. No end links	13 fm. $2\frac{9}{16}$ in. c.c. No end links
			4th	10 fm. 2¼ in. c.c. No end links	15 fm. 2¼ in. c.c. No end links
			4th	14½ fm. 2 in. c.c. No end links	21 fm. 2 in. c.c. No end links
			*5th	24 fm. 1⅝ in. c.c. No end links	35 fm. 1⅝ in. c.c. No end links
				PENDANTS FOR 20% RESERVE BUOYANCY	PENDANTS FOR 15% RESERVE BUOYANCY
5th 2 compartments	7 0	4 0	5th	9 fm. 1⅝ in. c.c. No end links	11 fm. 1⅝ in. c.c. No end links
			*6th	16 fm. 1¼ in. c.c. No end links	19 fm. 1¼ in. c.c. No end links
6th 1 compartment	6 0	3 9	6th	8 fm. 1⅝ in. c.c. No end links	9½ fm. 1⅝ in. c.c. No end links
			6th	15 fm. 1¼ in. c.c. No end links	17 fm. 1¼ in. c.c. No end links

* *Note:* A buoy sometimes has to be of higher classification than its mooring because of the depth of water.

TABLE 8-3

PERMANENT MOORING ANCHORS

Type of Anchor	Remarks	Weight of anchor in cwt	Maximum holding pull as a factor of anchor weight
Pick	Easily laid. Bites quickly.	36	2
		72	2
Admiralty Mooring Type 7 (A.M.7)	Needs more care in laying than the pick type. If practicable, it should be dragged into the bed after laying to improve its hold.	36	5
		72	5
		110	4*
Admiralty Mooring Type 12 (A.M.12)	Improved design, high-efficiency anchor, permitting a reduction in weight. This anchor will do the same work as would a 9-ton A.M. 7. When dragged, it will bury itself within one shank-length.	20*	14*
		42	14
		65*	14*

* Estimated figure for design weight not yet tested.

PART III

SHIP ORGANISATION

CHAPTER 9

Officer of the Watch in Harbour

'Every officer or person under the rank of Captain, not being the Executive Officer or the Commanding Officer for the time being, is to be subordinate to the Officer of the Watch, whatever may be his rank, in regard to the performance of the duties with which the Officer of the Watch is charged.'

This declaration from Chapter 1 of *Q.R. & A.I.* defines the status of the Officer of the Watch and should make clear to any officer acting as such how important is his position and responsibility. In a big ship in harbour there is normally an Officer of the Watch, but on occasions when there are very few officers available—and also in small ships usually—it is the custom to have an Officer of the Day, who keeps his duty for 24 hours. An Officer of the Day has the same status and responsibilities generally as an Officer of the Watch.

RESPONSIBILITIES

Officers should be familiar with all the Regulations concerning the Officer of the Watch. In this chapter some elaboration and explanation of the Regulations are given for the benefit of inexperienced watchkeepers in harbour. The same treatment for Officers of the Watch at sea will be found in Chapter 11.

In harbour the Officer of the Watch is responsible for the following:

The safety of the ship. This includes her safety from fire and collision; her security against unauthorised entry and sabotage; and her remaining safely at rest in her berth.

The safety of her company, which refers mainly to the safety of all men in exposed positions and aloft; of all crews and passengers embarking in, disembarking from, or under way in, boats; and of men over the side or bathing.

Protection of certain parts of the ship's equipment, such as brows, ladders and awnings.

The outward appearance of the ship and her boats.

The ship's ceremonial and marks of respect to be paid or received.

The orderly conduct of all on board, a responsibility normally exercised through, or with the help of, the Regulating Staff.

Supervision of the ship's routine and the organisation of all boat trips.

The safe embarkation of ammunition, fuel, stores and provisions.

Instruction of the gangway staff in their duties and the keeping of the prescribed records and books.

Since ships and circumstances differ so much, the notes given in this chapter must not be considered as complete. An Officer of the Watch must be prepared to act on his own initiative, keeping in view his overall responsibility for the

safety of the ship. If in doubt, however, he should not hesitate to ask the advice of his seniors, such as the Duty Commanding Officer, the Executive Officer or, if necessary, the Captain.

GANGWAY STAFF

Composition

The watchkeepers who assist the Officer of the Watch are collectively known as the *gangway staff*. Its composition depends on the size of ship and the time of day. For example, in a heavy ship such as an aircraft carrier, during the day watches, the gangway staff would comprise probably a Midshipman, a Quartermaster, a Boatswain's Mate, a Corporal of the Gangway, a messenger and a bugler. During the night watches there would only be a Quartermaster, a Boatswain's Mate and a Corporal of the Gangway. In place of, or in addition to, the Midshipman there might be an assistant Officer of the Watch, for example, a junior officer or a reserve officer under training.

In a small ship, such as a frigate, there will usually be only a Quartermaster and Boatswain's Mate, and they will keep watch both by night and day.

Badges of office

The Officer of the Watch wears a sword-belt and carries a telescope; the Midshipman of the Watch carries a telescope; the Quartermaster and Boatswain's Mate each carry a call and chain, and the Corporal of the Gangway wears a naval-patrol armlet round the cuff of his left sleeve. The object of these tokens is to make the staff instantly recognisable wherever they may be.

Duties

The staff should be alert and smart at all times, and never allowed to lounge about or chat to bystanders. Their most important task is to keep watch, that is, constantly to observe what is going on in the ship and her vicinity so that they will be the first to see anything amiss. In addition, each member has certain specific duties, which can be summarised as follows:

The Midshipman of the Watch (or Second Officer of the Watch) should understudy the Officer of the Watch and deputise for him when necessary. It is usual to delegate to him the running of the ship's routine and the boat routine, and he should always write up the Ship's Log and generally supervise the remainder of the gangway staff. In small ships the routine is usually left to be worked by the ship's company on time without continual broadcast reminders. For example, a coxswain will get his boat ready and report at the correct time to the Officer of the Watch for a routine trip without his boat being called away.

The Quartermaster is deputy to the Midshipman of the Watch and Officer of the Watch. He assists them as necessary and acts as required when, for example, the Officer of the Day is not on deck, or when there is no Midshipman. He reads the barometer, the hygrometer and the sea temperature at the required times, strikes the ship's bell when necessary and pipes any announcements over the broadcast system. He is in general charge of the after gangways and their accommodation ladders or brows, and should supervise the Boatswain's Mate, messenger and bugler.

The Boatswain's Mate assists the Quartermaster with his duties, calls reliefs, and deputises for him if he is absent going the rounds. If a midship gangway is open as well as an after one he is usually placed in charge of the midship ladder or brow.

Corporal of the Gangway. The Corporal of the Gangway is normally a corporal in the Royal Marines. If none are borne, his duties are carried out partly by the Quartermaster and partly by the ship's regulating staff. He keeps a security check on all incoming and outgoing parcels and packages to ensure that there is no illicit trafficking in dutiable goods or government property. He enters the names of all ratings proceeding on, or returning from, temporary duty ashore or in other ships in the *Gangway Duty Book.* He records in the *Gangway Wine Book* particulars of all wines, spirits, beer and tobacco received on board, for whatever mess or person, and also any disembarked. He takes charge of all correspondence other than Post Office mail and sees that it is delivered. He should go the rounds between decks at least once every hour in each watch during the night, and enter the results in the *Night Rounds Book.*

Equipment

The gangway staff have a clock and a desk that are situated normally in a small compartment under cover. In this place, called the Quartermaster's Lobby, or near it, the following gear should be kept and regularly mustered:

Binoculars
Large-scale chart of the harbour (or a photo-copy of it)
Hand lead-and-line
Sea thermometer
Aldis lamp
One or two electric torches, with spare batteries
Whistle
Some codline, spunyarn and about 20 fathoms of 2-in. cordage
Cleaning gear
Small fender
Inflatable lifejacket (for rescue)
Daily Orders
Radio Hazards Board
Gangway Wine, Duty and Night Rounds Books
Watertight Integrity Log
ABCD Door and Hatch Board
Captain's Standing Orders
Ship's Standing Orders
Ship's Log
Any temporary orders concerning the O.O.W.
Signal Log
Officers' Ashore-On Board Tally
Rough notebook

Dress

The dress regulations for dutymen are in the *Appendix to the Navy List.* On ceremonial and special occasions, and on Sundays during the forenoon, afternoon and dog watches, the dress of the staff should be No. 6 or 7. During the same periods on weekdays it should be No. 2, No. 7 or No. 10. During the night watches the dress is customarily night clothing. The details of dress to be worn on different occasions are, however, normally promulgated in the orders for the Station.

Records—Ship's Log

In addition to the *Watertight Integrity Log* (see page 243) and the books kept by the Corporal of the Gangway (already mentioned), the Officer of the Watch

is responsible for the correct writing up of the *Ship's Log*. Instructions for the compilation of the log are given inside its front cover. At the end of his watch the Officer of the Watch inspects the log to make sure that it has been properly completed, and initials it when satisfied.

TAKING OVER A WATCH

The Officer of the Watch should come on deck in good time to receive the turn-over before his watch begins, and should obtain the following information from his predecessor:

Safety of the Ship

The scope of cable to which the ship is riding, whether she is at single anchor, moored or made fast to a buoy.

If at single anchor, the condition of the second anchor (i.e. if it is ready for letting go or not).

If the ship is at anchor or moored, the anchor bearings.

The state of the berthing hawsers if alongside, and any adjustment required because of wind or tide.

The ABCD state and watertight condition of the ship.

The state of the Radio Hazards Board.

Notice for power on the main propulsion machinery.

Any programme for embarkation or disembarkation of ammunition, fuel, stores or provisions; the times at which any auxiliaries or lighters are expected alongside; or, if alongside, when they are expected to leave.

Employment of Boats and Ship's Company

Which boats are lowered, and if at the ship, how made fast; if away from the ship, what orders they have been given, and whether they are under sail.

The employment of the hands, what routine is in force; what men, if any, are working over the side or aloft; and which watch, or part of the watch, is on duty.

Discipline

State of men under punishment and in cells; any men absent over leave, and any investigation pending.

Various

The state of the brows, ladders and awnings and any information about the outward appearance of the ship.

The whereabouts of the Captain and the Executive Officer and, if they are not on board, who is acting as Commanding Officer; any special instructions in force for the O.O.W.

Any expected movements of ships in the harbour.

The berths of other warships in harbour, particularly flagships.

The state of the weather and a forecast, if available.

REPORTS TO CAPTAIN

As already remarked, the Officer of the Watch should not hesitate to consult his senior officers if in doubt; and if he considers the safety of the ship to be threatened he should inform the Captain, or, in his absence, the Duty Commanding Officer, immediately. Most Captains require in addition that the Officer of the Watch should report to them on the following occasions:

1. five minutes before hoisting and lowering the colours;
2. on any marked deterioration in the visibility or the weather;
3. on the arrival or imminent departure of a warship;
4. on sighting a boat under way carrying a flag officer with his flag flying;
5. on the approach of a boat carrying a captain;
6. if anything else of particular interest occurs.

SAFETY OF THE SHIP

Fire

The Fire or Emergency Party should be mustered and reported to the Officer of the Watch when they begin their turn of duty—usually at 1700, but on Saturdays, Sundays and make-and-mends usually at 1230. This is an important muster. Whenever the ship is in a dockyard the Fire Party should be exercised daily after the dockyard workmen finish work for the day.

The Fire Party are usually allocated special sleeping billets in one compartment so that they can be roused at night at a moment's notice. If a fire occurs it is best to pipe the Fire Party to muster at a place clear of the fire and near the stowage for their gear; they can then be given instructions as to the nature of the fire and how best to tackle it. If a fire occurs when the ship is lying alongside in a dockyard the dockyard police and fire brigade should be informed immediately, to ensure that assistance will be available should the fire spread or get out of hand.

Whenever dockyard workmen have been working between decks, the spaces in which they have been working should be inspected immediately after they have left the ship, and again half-an-hour afterwards.

The Officer of the Watch should be familiar with the regulations concerning the embarkation and disembarkation of dangerous materials and with the ship's organisation for putting them into effect. The following are the principal precautions against fire:

> Whenever any vessel carrying explosives or inflammable cargo berths alongside, all scuttles abreast her should be closed, the ship's company should be warned, and no smoking should be allowed on the upper deck on the side against which she is berthed. If a lighter is to remain alongside after work in her is finished for the day, she should be inspected and then her hatches or hatchboards should be replaced, covered and battened down.
>
> Whenever oil fuel or explosives are being embarked or disembarked, sentries should be posted and wireless transmission should be restricted. In the event of a thunderstorm the embarkation or disembarkation of explosives, oil fuel or petrol must be stopped well before the storm reaches the ship and not resumed until it has passed.

Collision

The most important precaution against damage resulting from collision is to keep strict control over the watertight integrity of the ship, and the responsibility for this in harbour is allotted normally to the Officer of the Watch. In certain large ships, however, control in harbour may be exercised from the ABCD Headquarters, which in this case is kept manned permanently, both at sea and in harbour. The O.O.W. should exercise control in accordance with the ABCD state of readiness and watertight condition in force. The system is described generally in Volume I, while details may be found in B.R.2170, *Ship A.B.C.D. Manual.*

The *ABCD Door and Hatch Board* is used for recording the overall watertight condition of the ship. In large ships it is fixed in the ABCD Headquarters, but in small ships it is portable, so that it can be placed where it can be supervised conveniently by the Officer of the Watch. In addition there is a *Watertight Integrity Log* in which the opening and closing of all openings that normally should be kept closed is recorded. The Officer of the Watch should see that both the Board and the Log are kept scrupulously up to date when they are under his charge, as they are usually in a small ship.

If threatened with collision, he should order 'Hands to emergency stations! Close all Red openings!' to be piped.

As a routine precaution at night, the watertight openings are usually brought to condition Y when the messdecks and flats are cleared up for rounds, and revert to the normal day condition when the hands turn to in the morning. If visibility deteriorates badly, the same condition (Y) should be ordered and the fog signal should be started.

Storm and tide

At anchor. In a storm or in an exceptionally strong tidal stream or current the chief danger is that of dragging the anchors and drifting on to a lee shore or into another ship. When a gale is imminent the normal precautions are to put the main propulsion machinery at immediate notice, clear away the anchors and cables ready for veering cable and for dropping a second anchor, and to set an anchor watch.

To discover if the ship is dragging, watch the compass bearing of any conspicuous object near the beam: if it draws forward this indicates that the ship is probably dragging.

If the ship is in no immediate danger, a more accurate method is as follows. Plot the anchor bearings (from the Ship's Log) on the largest-scale chart of the harbour. The fix obtained gives the position of the anchor when it was let go. From this point describe a circle of radius equal to the amount of cable veered plus the stem-to-standard distance. Fix the ship from the bridge and, if the position obtained lies outside this circle, the ship must have dragged her anchor.

It is obvious that if the anchor bearings were obtained from shore marks at short ranges the actual bearings of these marks from the bridge when lying at the full scope of the cable may differ considerably from the original anchor bearings. Thus a difference in itself does not necessarily mean that the ship has dragged. But if the shore marks were close, there may be little sea room in which to drag.

The first precaution to take is to veer more cable, so as to ensure that the cable is exerting a horizontal pull on the anchor. Further action is described on pages 368-371.

Alongside. When alongside, the possible dangers arise from the vertical movement caused by tide and from a horizontal to-and-fro movement caused by a scend entering the harbour. In some places it is essential to keep a continual watch on the berthing hawsers and to adjust them from time to time so as to ensure that each is bearing an even strain. Remember that the maximum rate of vertical movement occurs in the third and fourth hours of a six-hour tide. If a scend builds up it may be necessary to double up some of the berthing hawsers, or to put out hurricane hawsers.

Watch the brows carefully also. You may have to adjust their securing arrangements at intervals. If the ship is moving in the berth she may cause the shore ends of the brows to roll about on the jetty. If this happens see that people approaching the brows from ashore are warned of, and protected against, possible danger.

Danger from wireless and radar aerials

Dangers from this source are collectively known as *radio hazards.* They may affect men aloft or arise from risk of fire when embarking or disembarking dangerous materials or when moving them about on deck. The precautions needed are dealt with on page 197.

SECURITY OF THE SHIP

Unauthorised entry and trafficking

The Officer of the Watch is responsible that no unauthorised person enters or leaves the ship, and that no dutiable goods enter or leave the ship by any method whatsoever except under the control of the Corporal of the Gangway or regulating staff, and that no illicit trafficking is carried on over the ship's side or through scuttles. In some exotic harbours the arrival of a warship may arouse a certain enthusiasm for commerce, and it may be necessary to keep shore boats clear of the ship by means of hoses, and to prevent people clambering up the cable. Because fishing may be used as a cloak for smuggling, it is normally allowed only on deck and under supervision at certain times.

No gangway should ever be left unattended and no visitor should be allowed further than the gangway until his credentials have been checked. If in doubt, and also for politeness, see that a visitor is escorted to the person whom he wishes to see on board.

It may be necessary at night to close one or more gangways. If it consists of an accommodation ladder, this is hoisted and the guardrails are set up; if a brow, this can be closed by criss-crossing it with heaving lines, or alternatively by hauling it either on board or ashore.

Issue of keys

Keys of important compartments such as the spirit room, inflammable store, poison cupboard and pistol cupboard are kept separately and classed as *Important*

keys. Likewise the keys of all compartments in which explosives, projectiles or guided weapons are handled are classed as *Magazine keys*.

Key safes and key boards. In ships of cruiser size and above the Important and Magazine keys are kept in a key safe specially designed for this purpose. Two such safes are fitted, one in the ABCD Headquarters and the other near the Captain's cabin or in HQ2, or, if both the latter two places are inconvenient, elsewhere at the Captain's discretion. Each Commanding Officer has the discretion to decide which of the two key safes should—in any prevailing circumstances—be designated the Important key safe and which should be used as the duplicate.

In small ships the conventional type of keyboard is retained, with the Important and Magazine keys combined on one board. As the ABCD Headquarters may not be manned in harbour, the Important key board is placed in the Captain's lobby under the charge of the Officer of the Watch or Officer of the Day.

Books are provided (Magazine Log for the appropriate keys) to record names of persons to whom particular keys may be issued, and in which should be recorded particulars of the issue and return of each key and the initials of the person concerned.

The key to the poison cupboard may only be issued to the Medical Officer, or, with the Officer of the Watch's permission, to the Medical Officer's approved representative. If it is issued to the representative, its return must be reported to the Officer of the Watch.

At the end of each watch the Officer of the Watch should examine the Magazine Log to ascertain whether:

1. the records of the issue of keys agree with the state of the keyboard;
2. the records of magazine rounds during his watch have been entered and signed for;
3. the records of magazine temperatures have been entered during his watch;

and he should sign the log when he is satisfied that it has been correctly kept. If the log has been incorrectly kept he should inform his relief, who should take the necessary action to have the log completed correctly.

In small ships the Officer of the Day examines and signs the Magazine Log in a similar manner when he is relieved of his duties.

Night rounds

In order to ensure the safety of the ship and to prevent irregularities and possible acts of sabotage, the Officer of the Watch or Day and one of his staff should go the rounds between decks, and also on the upper deck, from time to time during the night watches. The rounds should not be done at fixed times or over fixed routes, and should be done about once every hour. In a big ship it is customary for the Corporal of the Watch to go the rounds, but in some large ships they are carried out by damage-control patrols. The times of starting and finishing the rounds are entered in the *Night Rounds Book*, which is signed by the Officer of the Watch on completion of his watch. It is important that one of the staff should always be left on watch on deck by the gangway while the rounds are in progress.

SAFETY OF MEN

Safety of men working over the side

Whenever men are working over the ship's side—when the side-party are touching up the boot-topping, for example, or when the hands are painting ship—vessels and boats passing close to the ship should do so at slow speed, and to ensure this it may be necessary to hoist the International Code signal TE.

Whenever divers are at work, either from the ship's side or from a boat near by, the red flag must be hoisted at the appropriate yard-arm and the diving boat should also display a red flag, and the signal TE should be hoisted.

In a strong tideway no man should be allowed over the ship's side without the Officer of the Watch's permission, and then only if he is wearing a lifejacket and has round him a strong lifeline (*not* a heaving line) which is tended inboard.

Radio hazards

Danger to men aloft from radio transmissions or from the rotation of radar aerials may arise from three causes:

1. Direct exposure at very close range to centimetric radar transmissions can produce internal heating of body tissues.
2. Although electric shock may not occur, sparks and slight burning may produce physical shock, thus causing a man to fall.
3. The unexpected start of a radar aerial rotating that has previously been stationary.

There is also the material risk of ignition of explosive or inflammable substances from radio transmission.

A practical balance must be struck between real dangers (as opposed to remote contingencies) and the operational need to transmit. In some cases work aloft may be quite safe and permissible while transmission is taking place, particularly for maintenance ratings who are aware of the dangers.

Radio transmissions and aerial rotation are normally restricted in the following circumstances:

1. when men are aloft;
2. when the ship is dressed overall;
3. when explosives are being embarked or disembarked, or handled on deck;
4. when inflammable stores or fuels are being embarked or disembarked, or handled on deck.

Restriction is controlled by the Officer of the Watch, who keeps a *Radio Hazards Board*. Certain circuit elements called *safe-to-transmit* and *safe-to-rotate* boards are removed from the transmitting sets concerned and placed on the board. It is then impossible for transmission and/or rotation to occur. The Radio Hazards Board is designed for a particular ship with her particular radio equipment. It will show what devices should be on the board to cater for a given condition—say, man aloft on the mainmast. The Officer of the Watch must see that no man goes aloft without first obtaining his permission and placing the appropriate safety devices on the board. The Captain may authorise certain officers to relax precautions, in consultation with the Officer of the Watch, for essential operation or maintenance of sets in special circumstances.

Hands to bathe

Whenever hands are piped to bathe alongside the ship a boat equipped with a lifebuoy attached to a lifeline should always be in attendance to go to the rescue of any bather in difficulties. A dinghy manned by two men is very suitable for the job, and it should be stationed about 50 yards from the ship to mark the outside limit of the bathing area. Bathing should be under the supervision of an officer, and should be allowed only on one side of the ship; in tropical waters a good lookout should be kept for sharks.

Never allow bathers to get down-tide, or to leeward in a strong wind, or to swim outside the bathing area. If there is a swell, jumping ladders and scramble nets for bathers to climb on board should be rigged. The heads and gash chutes on the side on which bathing is to take place should be closed ten minutes before the hands are piped to bathe.

Libertymen

The Officer of the Watch should always supervise the embarkation and disembarkation of libertymen at the gangway, maintain strict silence among them both on board and in the boat while it is in progress, and, having regard to the state of the weather and the experience of the coxswain, should not allow any boat to be overloaded. It is the custom for senior ratings to enter or leave a boat before junior ratings. No one should be allowed to rest his arm or hand on the gunwale of an open boat, because of the danger of having it crushed. After sunset a light should be rigged at the gangway to illuminate the accommodation ladder and any boat alongside.

When many libertymen are landed an officer may be sent with a pier patrol to act as a piermaster at the landing-place and ensure the safe embarkation of libertymen in their boats.

When a boat returns to the ship with libertymen, particularly after dark, one of the gangway staff should be stationed on the lower platform of the accommodation ladder to assist men getting out of the boat when necessary. A careful watch should be kept for men who appear incapable of getting out of the boat unaided; such men, and any who are utterly incapable, should be got out last of all and with lifelines round them.

When the ship is alongside, the approaches to the jetty end of the brows should be kept clear of obstacles, and at night they should be well illuminated. When the ship is in dock the dockside guardrails should always be in place, and at night the route to the brow should be kept clear and well lit.

BOATS

Organising boat routine

The Officer of the Watch is expected to see that boats are alongside the gangway by the times laid down in the boat routine, and that they leave the ship punctually. Coxswains of boats must report personally to him for orders before they man their boats. Libertymen should be piped in time to ensure that the boat can leave at the routine time.

Boats should be refuelled at the times laid down. If this is not possible, plenty of warning must be given to the engineering department to provide the fuel when required. Batteries in boats should be checked daily.

The provision of extra boat trips for special purposes must not be allowed to disrupt the boat routine. Special trips should be combined with routine trips whenever possible. If in doubt on the advisability of providing a boat for an out-of-routine trip the matter should be referred to the Executive Officer or the Duty Commanding Officer. But with a little tact and ingenuity the Officer of the Watch should be able to arrange all the various boat requirements so long as they are reasonable. He must know how long it takes the boats to go to different parts of the harbour.

Boats' crews should, as far as possible, be allowed the regulation periods for their meals. If a boat is likely to be away during a meal hour the galley staff should be warned in plenty of time so that the meal is not over-cooked, but is kept hot until the return of the crew. If a boat is away during the dinner hour the spirit ration of the crew should be drawn and issued to them later as miss-musters.

If no boats are in the water, there must be some organisation in force to provide a boat and crew at night at short notice in the event of emergency.

Boats at the booms

Whenever a boat is made fast to a boat boom the coxswain should report the fact personally to the Officer of the Watch. All loose gear in the boat should be secured, the fenders should be placed (except on the outer side of a boat at the outer billet), no gear should be projecting or hanging outboard of the boat, and she should be riding comfortably with the correct amount of scope on her painter or boatrope. She should be clear of possible discharges from pumps, etc. from the ship's side.

If there is any likelihood of bad weather it is advisable to hoist all boats except duty-boats before dark, and at the same time to reeve boatropes and sternfasts for those boats which are to remain down overnight. Hoisting boats, even as a matter of routine, should always be regarded as an evolution and carried out smartly. Boatropes are normally unrove when the hands turn to in the morning, unless the weather is rough or there is a tidal stream running.

If the boats are bumping against each other or against the ship's side, or when the ship is swinging at the turn of the tide, the crews should be ordered to man their boats.

If a gale is imminent it is wise to hoist all boats. If a boat has to be left down it is best to send her inshore to shelter before the weather gets too rough, if there is a safe berth for her there. If this is impracticable she should be made fast astern, possibly on a hawser, because she will ride more easily there than at the lower boom. If the seas are breaking heavily a little oil dripped continuously from a bag slung over each bow of the ship will stop them breaking.

Boats alongside

A boat should never be allowed to lie alongside for longer than is strictly necessary; she should be ordered either to make fast to a boat boom or to lie off.

When a boat comes alongside, except in calm conditions, the gangway boat-rope should be lowered to her and she should always make fast to it. It is unseamanlike to allow a boat to lie alongside unless secured to the boatrope. If ladies are arriving or leaving, the Midshipman of the Watch or one of the gangway staff should be sent to the foot of the ladder to help them disembark or embark.

In a strong tideway a tide spar should be rigged before the foot of the accommodation ladder to prevent boats from getting jammed under it.

If the ship is moored head-and-stern to buoys in a tideway, tide spars should be rigged abaft the foot of the accommodation ladder as well as before it, and an extra boatrope should always be rigged abaft the ladder for use by boats coming alongside head-to-stern.

Precautions before leaving the ship

Before a coxswain is ordered for the first time to go to a certain landing-place he should be shown the plan of the harbour or anchorage, his course there and back, and any navigational dangers along his track. If the course is long and complicated he should be provided with a plan of the harbour or a tracing of it. He must have a watch or a clock in the boat.

All coxswains of boats should know the times of high and low water, the range of the tide and the time of sunset. It is a good plan to post these conspicuously above the gangway desk.

Although the coxswain is primarily responsible for the state of his boat and her crew, it is the duty of the Officer of the Watch to see that the crew are properly dressed and the boat shipshape. When time allows it is advisable occasionally to check various items of a boat's equipment, such as the lifebuoy in power boats, lifejackets for the boat's crew, the ground tackle, the boat's slings, and the boat's signal book. In rough weather each member of the crew should wear a lifejacket. Members of boats' crews must be able to swim. If a boat is to be away after sunset her navigation lights should be shipped and in working order. If a boat is to be sent on a long out-of-routine trip, make sure she has sufficient fuel for the trip there and back.

It has already been pointed out that the Officer of the Watch must see that no boat is overloaded when she leaves the ship. But he should also give the coxswain definite instructions, if the weather looks like deteriorating, as to what should be his maximum load in rough weather on the return trip, and about where to shelter if the weather is too rough to risk a return passage at all.

No one should be allowed to take away a boat under sail without supervision until he has proved himself to be a competent helmsman. It is customary for the Boat Officer to promulgate a list of those members of the ship's company who are allowed to take away boats under sail, and the Officer of the Watch should check aspiring coxswains with this list.

Boats away from the ship

The Officer of the Watch must see that the flag deck keeps a good lookout on the ship's boats and on all boat traffic near the ship, and he should send help at once to any boat in difficulties.

An occasional signal made to the ship's boats when they are away from the ship will prompt coxswains to keep an eye on their ship.

If a boat is going on a long trip out of sight of the ship the Officer of the Watch must satisfy himself that the coxswain and crew are fully prepared to look after themselves should the weather worsen, and that they know by what time they are expected back. It may be necessary to provide the crew with a portable radio with which to keep contact with the ship. If in any doubt, the O.O.W. should restrict recreational trips to an area within sight of the ship.

It is by no means an uncommon event for a modern sailing dinghy to be capsized even in a moderate breeze by an experienced helmsman. To make certain that such an event is not a disaster, however, the following precautions must always be observed:

1. Helmsman and crew must wear lifejackets.
2. Dinghies must have adequate built-in or inflatable buoyancy to support both the boat and crew in the water after a capsize.
3. Sailing in dinghies is to be carried on only under observation from the ship or in a place frequented by other boats.
4. A dinghy must never be overloaded either with crew or stores, e.g. picnic gear.

Duty despatch boat

When in company with other ships the Senior Officer will detail one ship daily to provide a despatch boat to collect fleet correspondence from each ship and deliver it to the Senior Officer's ship, and to collect fleet correspondence from the Senior Officer's ship and distribute it among the other ships. The ship providing the boat also provides a mail orderly. Keep a good lookout for the despatch boat and do not keep her waiting alongside for longer than is necessary.

All fleet correspondence should be ready before the expected time of arrival of the boat on her collection trip. The mail orderly should report to the Officer of the Watch on deck and any correspondence should be handed over there. Handing over or receiving mail at the foot of the accommodation ladder is a bad practice; it may save a little time, but can easily result in the mail being dropped between the ship's side and the boat.

Appearance of boats

Boat's crews should be correctly and uniformly dressed in the rig ordered and should wear their caps with the chin-stays down always. The normal rig for boats' crews from 0800 to 1830 is No. 1, No. 2, No. 6 or No. 7 and from 1830 to 0800 night clothing. The rig for crews of boats calling alongside foreign warships, day or night, should be No. 2; but if the boat is carrying the Officer of the Guard between sunset and sunrise, her crew may be dressed in night clothing.

Boats' crews should always wear clean white gym shoes. In rough weather they wear foul-weather smocks and trousers and lifejackets.

It is an old saying that a ship is known by her boats. The Officer of the Watch can do much to enhance the reputation of his ship by seeing that all boats under his orders are clean and shipshape, that their crews are smart both in appearance and drill, and that they are handled in a seamanlike way. Do not hesitate to find

fault with boats and to let it be known that you expect a high standard. On the other hand, always remember to praise a coxswain if his boat looks specially smart, or if he handles her well in difficult circumstances.

PROTECTION OF SHIP'S EQUIPMENT

The protection from the weather and its effects on the ship's equipment situated on the upperdeck, in the superstructures or outboard is generally the responsibility of the Officer of the Watch. Remarks on the handling and care of awnings are given in Volume II. The main need is to keep a lookout for the approach of squalls or rain and to have the awnings sloped and if necessary frapped *before* the bad weather arrives at the ship. The same applies to the covering of the armament. If a flagship is in company it is customary to follow her actions over awnings, covering guns, etc.

The Officer of the Watch should remember that natural-fibre cordage shrinks when wet and that it is often necessary to check frapping lines, awning tackles, etc. after rain to prevent distortion and damage to awnings.

In rough weather the accommodation ladders should be hoisted clear of the water if waves are breaking over their lower platforms, and a well-fendered jumping ladder should then be rigged well aft on each quarter (abaft the screws) where there will be the best lee for boats coming alongside. It may be necessary to rig a stern or a quarter boom for the boats.

APPEARANCE OF SHIP

In matters concerning the outward appearance of the ship, for which the Officer of the Watch is responsible, it is also customary to follow the movements of the senior officer or flagship. Examine the following points on taking over your watch, and see that your subordinates pay attention to them also throughout the watch:

Colours. The ensign, jack and masthead pendant or distinguishing flag should be hoisted close up with their halyards taut, and they should not be foul of or turned around staffs, mast or nearby rigging.

Armament and rotatable aerials. If not in use, these should be placed in their proper positions fore-and-aft or as laid down in the ship's orders.

Halyards, particularly signal halyards, and other parts of the rigging should be set up taut if not in use.

Boat booms should be square with the ship's side, both in the horizontal and the vertical plane. The bights of boat ropes should not be allowed to trail in the water when they are not in use.

The *ship's side* should be clear, and there should be no ropes or fenders over it. Any shore boats should be kept well clear of the ship and such boats never be allowed to make fast alongside, astern, or to the anchor cable.

Accommodation ladders should be rigged squarely, and the end of the gangway boatrope and its check line should be cheesed down on the upper platform. The supports of the lower platform should be kept clear of any flotsam.

Awnings should be taut and square. The hauling parts of the falls of the awning tackles should be cheesed down.

Davits of boats which have been lowered should be turned or canted inboard; the lower block of each fall should be secured to the heel of its own davit and the falls then rounded up and reeled up. It is not a good practice to cross the falls to the heels of the opposite davits, because this may chafe the falls, as they are rounded up, in passing through the upper standing blocks.

Clothes lines are provided in some ships, and an order is promulgated as to when and how they should be used. The Officer of the Watch should see that the clothes on the lines are properly secured, with no holidays between them, and that no clothes are hung up except on the proper lines and at the authorised times.

When *Air bedding* is piped the Officer of the Watch must see that the bedding is neatly secured along the top guardrail, with no holidays.

CEREMONIAL

The Officer of the Watch is responsible for ensuring that the necessary marks of respect are paid to passing ships or boats carrying senior officers, and to officers arriving on board or leaving the ship. Remarks on salutes and other marks of respect are given in Volumes I and II.

If a boat carrying a senior officer approaches and the Captain is out of the ship, the Officer of the Watch should, as a matter of courtesy, go to the foot of the accommodation ladder as the boat comes alongside and tell the senior officer that the Captain is away.

In a busy fleet anchorage it is advisable to detail a lookout to keep a watch for approaching ships and for boats flying distinguishing flags or pendants.

DISCIPLINE

Regulating staff

As already noted, the Officer of the Watch, under the Executive Officer, is responsible that the Master at Arms, and any ratings employed on regulating duties, carry out their duties in accordance with *Q.R. & A.I.* The latter cover such things as the conduct of patrols and escorts, the control of libertymen and men under punishment, the supervision of rounds at night, the rum issue and those duties normally done by the Corporal of the Gangway. Some of these subjects have already been discussed, and every Officer of the Watch should be familiar with the Regulations concerning those not specifically mentioned in this chapter.

Investigation of disciplinary cases

The quarterdeck is the usual place for the investigation of disciplinary matters, and the Officer of the Watch is responsible for the primary investigation of all such matters. He should not, however, allow investigations to interfere with his other duties. If the investigation of a case appears likely to be long and complex he should ask for a relief to carry out his other duties or ask for another officer to investigate the case.

Charges. It is most important that any charge preferred against a man is worded correctly. Before the Officer of the Watch interrogates the accused in serious cases which may lead to a court martial, he should read to him the prescribed warning about any evidence he may give. Charges against petty officers and serious charges against other ratings should be preferred by a regulating petty officer, and charges against chief petty officers should if possible be preferred by the Master at Arms. Any charge against a senior rating should, whenever practicable, be investigated in a place clear of junior ratings.

Search. Chief petty officers and petty officers are exempt from personal search unless it is specifically ordered by the Executive Officer or the Captain. Leading ratings are exempt from personal search unless it is specifically ordered by the Officer of the Watch, the Executive Officer or the Captain. If a man's kit is searched, the man and his divisional officer, or another officer, should be present at the search. If no officer is available the kit should be searched on the quarter-deck under the supervision of the Officer of the Watch.

Drunkenness. The decision as to whether or not a man is drunk rests with the Officer of the Watch, and the criterion in regard to drunkenness is whether or not the man is fit 'to be entrusted with' his duties. If, however, there is any doubt whether the man's condition is due to alcohol or to some other cause the advice of the Medical Officer should be obtained. Any altercation with a drunken man should be avoided and care must be taken to prevent him from aggravating his offence.

A patrol is fully competent to state that a libertyman is drunk if they apprehend him ashore. Even if he has sobered by the time he has returned to the ship, the man is still answerable to the charge of being 'drunk on shore', and the Officer of the Watch may not dismiss such a charge.

A drunken man should be placed in confinement to prevent him from aggravating his offence and from injuring either himself or his messmates. Before a man who is incapable is placed in confinement he should be examined by the Medical Officer, because when in such a condition he may require medical attention. Whenever a man is placed in confinement the Commanding Officer and the Executive Officer should be informed. A drunken man who has been placed under restraint should be released as soon as he is considered to be sober.

Fighting. When investigating cases of fighting or altercation the participants should be kept well apart from each other to prevent any further outbreak of violence. If the difference between the two cannot be settled, and if they are of equal rate and appear well matched physically, they may be offered the opportunity of settling the argument by fighting it out in a boxing ring under the supervision of an officer.

Loss of stores. The loss of any stores or equipment, either by accident or neglect, must be investigated by the Officer of the Watch, and the loss of stores valued at £5 or over must be recorded in the ship's log.

EMBARKATION OF DANGEROUS MATERIALS

Before the arrival of a vessel or lighter alongside there should be nothing projecting outboard in her way and, where necessary, davits and boats should be turned in, boat booms housed and accommodation ladders hoisted inboard.

Fenders and catamarans should be placed in position and a small berthing party detailed. Out of working hours the duty hands, assisted by members of the gangway staff, should be sufficient. It is important to be prepared for the arrival of a lighter and not to keep her waiting unnecessarily. She probably has several other ships to visit as well as your own. An officer should always be in charge when ammunition, stores or provisions are embarked or disembarked.

The precautions to be taken against fire when embarking or disembarking explosives, oil fuel or petrol have been mentioned on page 193, and precautions for wireless and radar aerials on page 197. When embarking or disembarking ammunition, only the authorised slinging and hoisting gear should be used.

When stores or provisions are to be embarked or disembarked the Supply Officer should be asked beforehand for details of their quantity and types so that the necessary number of men can be detailed for the job and the necessary gear prepared. When embarking or disembarking stores or provisions, a member of the supply staff should be present, and a net should be slung between the ship's side and the gunwale of the vessel or lighter to catch anything which may fall from the hoists. When embarking or disembarking mails or kit, a member of the regulating staff should be present.

RUNNING THE ROUTINE

In ships nowadays more emphasis is placed on each individual being responsible for going to his place of duty at the time ordered in the published routine or daily orders, and less emphasis on the continual piping of the routine and mustering of men before they start work. A time check is given early in the morning, and from then on the routine virtually runs itself. However, the Officer of the Watch must see that any routine announcements ordered for particular times are properly piped at precisely the right times; and he must make any routine reports to the Executive Officer at exactly the times required. No pipe should ever be made without the authority of the Officer of the Watch.

Piping and announcements generally should be kept to the minimum, and the number of words used in standard pipes should also be reduced to the minimum. For example, 'It is requested that Commander Brown may come to the shore telephone to speak to Major Smith' may be cut to 'Commander Brown—shore telephone'. Such abbreviations in the long run prevent the continual irritation and distraction caused by excessive broadcasting, especially to those not affected.

The Officer of the Watch must be quick to inform the Executive Officer or other heads of departments about any occurrences that will require a change in the routine, or which will entail some preparation or organisation for the next day or at some future time.

CHAPTER 10

Ship Upkeep, Fittings and Stores

This chapter is divided into five main sections: UPKEEP, DOCKYARD ORGANISATION, MAINTENANCE ORGANISATION, SHIPS IN RESERVE and FITTINGS AND STORES. The aim is to provide the seaman officer with a guide to the principles of planned upkeep in the Service, with an outline of the working of the Royal Dockyards and the organisation of the Reserve Fleet, and a summary of the various types of fittings and stores used in H.M. ships.

UPKEEP

Upkeep may be defined as the whole range of activities required to maintain the designed performance of a ship and her equipment throughout her useful life. Upkeep is divided into *maintenance*, which is normally carried out by the ship's staff and fleet resources; and *repair*, which is normally carried out by the Royal Dockyards (and occasionally by ship-repair firms) or by fleet repair ships. Every ship needs upkeep. The requirement can either be met in a planned and organised way, or it will be imposed as a result of breakdown. It cannot be escaped.

All departments in a warship, and not least the seaman branch, are involved in her upkeep. Maintenance of the hull and of those parts of the ship that are not the responsibility of the technical and maintainer departments is collectively known as *ship husbandry*. The term includes maintenance, for example, of anchors and cables, rigging, boats and upper-deck gear generally. Notes on the maintenance of the seaman's gear are given throughout the volumes of this manual in the relevant chapters. There is a chapter summarising the practical aspects of ship husbandry in Volume II. Further details of the subject are in B.R. 2203, *Ship Husbandry Manual.*

PRINCIPLES OF PLANNED UPKEEP

Need for planning

In modern designs of warship the task of upkeep is far more exacting than formerly. Suitable periods must be allowed for maintenance by the various departments of the ship, in addition to docking and repair periods in dockyard hands. In short, upkeep must be allowed for when planning a ship's programme throughout a commission. If this is done it will be possible to attain the maximum sea-going usage of the ship. Conversely, if it is not done the material condition of the ship will deteriorate, leading eventually to breakdown of equipment, which in the long run causes a heavier cost in upkeep, both in repairs and through time lost from operations.

Preventive upkeep

Preventive upkeep consists of regular servicing and attention to equipment in order to keep it continuously effective. It involves work designed to minimise wear and deterioration, such as lubrication, cleaning and painting; and periodic examinations and tests of equipment to reveal incipient defects. By this means minor defects can be prevented from developing into major breakdowns, and the general condition of equipment can be assessed so that the time when it will need overhaul or replacement can be forecast and planned for.

Preventive upkeep can never eliminate breakdowns entirely. To aim at this would entail an uneconomic expenditure of time and effort. A balance must be struck between work on preventive upkeep and that on repair of defects and breakdowns. If properly organised, however, preventive upkeep can combine the maximum standard of performance and reliability with the most economic expenditure of effort, and should give the ship generally a margin of serviceability with which to meet the demands of emergency operations or war.

Maintenance schedules

A detailed plan for preventive upkeep on a particular item is called a *maintenance schedule*; it is the means whereby the optimum amount of preventive upkeep is done. The schedule provides a guide to the maintainer and indicates to him that if he does more preventive upkeep work than that given in the schedule he will not achieve an improvement in efficiency commensurate with the extra effort; whereas if he does less he can expect breakdowns and lack of reliability.

UPKEEP ORGANISATION

Ship maintenance authorities

The upkeep of a ship is the responsibility of her Commanding Officer, but, since the planning of upkeep of warships has become so complex, a special organisation exists in the Royal Navy to deal with it. The maintenance schedules for a ship or class of ship can be worked out accurately only after a mass of data has been collected and analysed. Special authorities exist to collect and analyse these data, and then to issue to ships all the instructions necessary for them to plan their own upkeep. These authorities are known as *ship maintenance authorities*. For example, at present the Commander-in-Chief, Portsmouth, is the ship maintenance authority for all aircraft carriers, cruisers, guided-missile destroyers and a number of other classes of ship. The Commander-in-Chief, Plymouth, is the ship maintenance authority for frigates, destroyers and some other classes; while the Flag Officer, Submarines, is the ship maintenance authority for submarines and submarine depot ships.

In addition to the collection of data and the issue of maintenance schedules, the ship maintenance authorities advise the Admiralty and Commands on what cycles of operation, maintenance and repair will produce the maximum availability of ships for service in war and their most economic operation in peace. The ship maintenance authorities' knowledge of upkeep problems in ships enables the Admiralty to improve the design of new ships or alter existing ships and to make changes in ships' complements, so as to make upkeep easier and more efficient.

Standard documentation system

The practical implementation of preventive maintenance and planned upkeep through the ship maintenance authorities involves the issue of standard sets of documents to ships and standard reports and returns from the ships. It is not necessary to give details of this system here; the essential features are as follows:

Maintenance Schedules. These are issued to ships and give detailed guidance for each department on the preventive upkeep needed for each item of equipment. Each maintenance schedule is a complete statement and embodies all maintenance instructions, even if some of these are also issued elsewhere, e.g. in B.R.s or in *Q.R. & A.I.*

Bring-up and Planning System. This is a card system which enables the work of the maintenance schedules to be broken down into individual items of work, each of which is entered on a card. Not only can the card be issued to the man who actually does the job, but the arrangement and movement of the cards in their stowages can show the officer in charge what is the state of progress of the upkeep work and what his future commitments are, so that it is easier for him to organise his staff and to plan ahead.

To make this complete, it is necessary to put each defect or breakdown also on a card as soon as it occurs, so that not only are the scheduled, but also the unscheduled, items of upkeep work represented on the cards in the system. The cards showing defects are called *job cards*, and they replace the defect books kept in ships under the previous system. If the defect can be, and is, remedied by the ship's staff, the job card is disposed of; if not, it remains in the card system and so facilitates the preparing of complete and accurate defect lists from each department when the ship goes into dockyard hands for refit. In addition, any proposals for Alterations and Additions (which are described on page 210) are recorded initially on job cards. If the Captain wishes to be briefed about outstanding defects in any department, the relevant job cards can be extracted and put in a folder to be shown to him.

Records and returns. Instructions are issued to departments about various permanent records concerning the upkeep and usage of equipment and machinery. In addition, the system depends upon ships rendering returns to their ship maintenance (and administrative) authorities each quarter showing their state of upkeep. These returns include a ***maintenance return***, which shows the progress with the maintenance schedules; a return of ***hull-structure inspections, examinations and air tests*** and a ***defect return***. The defect return shows all the defect items that have been inserted on job cards, and a copy can be sent also to the appropriate repair ship or base, marked up in such a way that it will show the extent of the work to be undertaken during the next maintenance period or refit.

Defects

If the maintenance schedules are being followed conscientiously, and if all defects are recorded on job cards as soon as they are discovered, a ship adopted by ship maintenance authority will have no difficulty in compiling comprehensive defect lists that will enable a dockyard to plan and cost the work of a refit accurately and quickly. In a ship not adopted by ship maintenance authority

each department keeps (in place of job cards) a *Departmental Rough Defect Book*. Defects listed are divided into two categories:

1. those which can be remedied by the ship's staff,
2. those for which dockyard assistance is essential.

Defects in the second category, and any which cannot be repaired by ship's staff while the ship is still running, are then transferred to the *Ship's Record of Defects*, which is inspected by the Captain each week. It is from this record—or, in the case of a ship-maintenance authority ship, from the job cards—that the *main defect lists* are compiled. These defect lists are forwarded so as to reach the refitting authority concerned several weeks before a refit is due to begin, so as to enable the dockyard to assemble the materials and labour necessary to effect the repairs. *Supplementary defect lists* should contain only defects that have arisen since the despatch of the main defect lists, or those which are brought to light by dockyard examinations and tests during the refit.

Defects on either list are sub-divided as follows:

1. *Pink Defect List*. So-called because the form used (S.340) is printed on pink paper, this list contains only repairs essential for the fighting and sea-going efficiency of the ship. Also included in this list are repairs to, or replacements for, first-fitting sea stores (as defined on page 223) and requirements for surveys, routine examinations and tests by the dockyard.
2. *White Defect List*. Printed on Form S.340B (white), this list comprises all the other defects required to be made good by the dockyard. Also included on this list are demands for spare gear, portable fittings and similar equipment.
3. Work to be undertaken by the ship's staff during the refit with the assistance of the dockyard is also recorded in both the Pink and White defect lists. This work is further sub-divided into that for which *finished* materials and that for which *unfinished* materials are to be supplied by the dockyard.

Under the ship-maintenance authority system there are also certain items in the maintenance schedules which are undertaken by dockyards and which have the same status as defects affecting seagoing and fighting efficiency.

An inaccurate or inadequate defect list can cause a great deal of unnecessary work and waste of time. It is most important that defects are correctly and fully described, and that the rules which accompany the defect forms are carefully followed. This will enable the dockyard to make a correct allocation of men, money and materials.

Alterations and Additions

The term *Alterations and Additions*, commonly called *A's and A's*, is used to describe improvements to the structure, machinery, armament or equipment of a ship to enhance her seaworthiness, fighting efficiency or habitability. Proposals for A's and A's may be initiated in the Fleet or by Admiralty departments, and if approved by the Admiralty each is classed A, B or C according to which of the three following categories it belongs to:

A—items essential for the sea-going or fighting efficiency of the ship, or for her habitability;

B—items which cannot be classed as A, but which are approved for incorporation in existing ships when the opportunity occurs;

C—items which, though not meriting the cost of carrying them out in existing ships, should be incorporated in future design.

In larger ships and in surveying vessels, the Captain is responsible for co-ordinating the various A's and A's approved for his ship and for forwarding the necessary returns to his administrative authority. In frigates and smaller vessels a co-ordinating authority, such as the squadron commander, is detailed by the Admiralty. Items in category A are recorded by the co-ordinator on Form S.1182, and those in category B on a separate list, and both are forwarded by the co-ordinator through his administrative authority to the Admiralty on completion of building or refit, and also nine months before the start of any modernisation, conversion or special refit (see page 211).

Details of all A's and A's, whether proposed or approved, are recorded on Form S.345, *Record of Alterations and Additions*, which is kept in all ships, and from this record the lists of A's and A's for categories A and B are prepared.

Alterations and Additions in category A may be carried out during a periodical refit, but those in category B are usually effected only when a ship is undergoing modernisation, etc. A's and A's which can be done by the ship's staff, however, may be taken in hand as soon as an opportunity occurs.

Admiralty approval of an A and A does not necessarily mean that it will be carried out at the first opportunity, or even during a periodical refit, because this depends largely on whether the necessary labour and materials are available. Any which are essential for the safety of the ship, however, are taken in hand at the first opportunity.

REPAIR ORGANISATION

Role of the dockyards

As defined at the beginning of this chapter, the term 'repair' includes all forms of upkeep which are generally beyond the capacity of ship and fleet resources, but which are normally carried out by the Royal Dockyards and occasionally by commercial contract or by fleet repair ships. The primary role of the Royal Dockyards is to deal with the repair and modernisation of the fleet. Certain periods are set aside in the ship's programme for docking and refitting. The upkeep organisation already described is so designed that ships will not need dockyard assistance outside these periods except in the case of damage or major unforeseen breakdowns.

Role of repair ships

Repair ships are intended to provide the same type of facilities as a dockyard, but on a limited scale. They are normally used in conjunction with a floating dock. Their primary role is to make good action or weather damage and urgent defects beyond normal fleet or ship capacity to repair, especially in an area remote from shore dockyards.

Types of refit

The following terms are used to define the various types of refit:

Modernisation. Major work involved in bringing a ship up to date, including extensive renewal of equipments, and refit by survey, the function (e.g. destroyer) of the ship remaining unchanged. Ships are paid off into dockyard control usually during modernisation.

Conversion. As for modernisation, but the work includes changing the ship's function, e.g. conversion of destroyer to anti-submarine frigate.

Special refit. A refit supplementary to the normal refitting cycle, covering defect lists but also making certain major Alterations and Additions. Ships are reduced to long-refit-procedure complement.

Long refit. A comprehensive refit covering defect lists but with the additional aim of restoring the ship's material condition and bringing her up to date as far as possible. Occurs at intervals of about six years, and the period in hand is longer than for a *normal refit*. Ships are reduced to long-refit-procedure complement.

Normal refit. Routine refit and repair covering defect lists and occurring at intervals specified in the operating characteristics for the class of ship. Ships normally remain in full commission.

Intermediate docking. Routine docking and essential repairs carried out between normal refits at intervals specified in the operating characteristics for the class of ship.

Unprogrammed work. Work carried out outside the periods specified above, e.g. work arising from accident, damage, unexpected operational requirements and similar contingencies.

Dates of starting and completing refit, etc.

It is important when planning ship's programmes that the dates of starting and completing the refit, or of completing the construction of a new ship, are given precise names and meanings so that all authorities concerned know exactly what is intended. The following terms therefore are used always:

Date	New Construction	Modernisation, Conversion or Refit
Non-operational date	Not applicable	The date on which preparation (e.g. de-ammunitioning) begins. Usually one week before refit.
Start date	Not applicable	The date on which the ship is actually taken in hand by the yard.
Terminal date	Not applicable	The date by which repair and installation work is finished but with trials and painting still outstanding.
Completion date	The date of the Admiral Superintendent's inspection. Ship ready for final sea trials.	The date by which all work (including basin and harbour trials) and painting is complete and the ship is ready for full commissioning and sea trials.
Operational date	The date by which the ship is ready to start working up, i.e. after ammunitioning, storing, ship-staff trials (including sea trials). To be decided by the administrative authority.	

Trials

Certain trials proceed during the course of the refit—for example, the testing and tuning of main propulsion machinery, particularly of the internal-combustion kind. After the refit has been completed the number of trials required will depend on the extent of the repairs carried out. After a normal refit the trials usually cover only those items which have been fitted, altered or repaired. After modernisation, conversion, special or long refit, or in a newly-constructed ship or one commissioned from the reserve, the trials are more comprehensive and will cover every item of equipment. There will be a basin trial of the main propulsion machinery, followed at sea by full-power and fuel consumption trials, starting, stopping and astern trials, and possibly also turning trials (as described in Chapter 12). In addition, there will be radio and radar trials, weapon tests and firings, calibration and adjustment of direction-finding gear, compasses, radar, etc. In certain ships, such as aircraft carriers, there will be trials of the specialised equipment carried. Programmes of trials are arranged jointly between the ship's officers and the dockyard officers.

Work-up

In a newly commissioned ship the period of trials is normally followed by a period of several weeks' *work-up*. This period is designed to exercise the ship's company at every kind of work and to raise the efficiency of the ship generally to the standard required to undertake her task with the Fleet. The work-up is incidentally a further test of the efficiency of the repairs done and the upkeep organisation as a whole, but in order to make the most of the work-up all the ship's equipment should have been fully tried and tested before it begins.

PREPARATIONS FOR REFITS

Refit conference

As soon as possible after the ship arrives in a dockyard for a refit, a conference is held between the ship's officers and the dockyard officers; it is presided over by the Superintendent of the Dockyard or his deputy, the Captain or Commander of the Dockyard, or by a representative of the Constructive Department. At this conference the ship's defect lists and the list of approved Alterations and Additions are discussed in detail and decisions are made as to which items shall be undertaken during the refit, the division of work between the dockyard and the ship's staff is agreed upon, and the refit programme is arranged. The limiting factor is, of course, the money that can be made available by the Admiralty.

Preparation for normal refit

The principal arrangements for a normal refit include: allocation to a berth under a crane for a part or the whole of the refit period, depending on what lifting is required; dates and times of moving the ship from one berth to another; dates and times of docking and undocking; provision of locked storage in the ship for workmen's tool boxes; dates of the start and finish of any work in spaces or compartments, such as mess decks, bathrooms, galleys and storerooms, and arranging them to fit in with the ship's programme of leave, storing, ammunitioning, etc.; provision of any portable boilers and shore galleys required; clearing

stores or equipment from compartments which are to be surveyed, tested or repaired, and providing *lay-apart* storehouses for them on shore; and, finally, the terminal, completion and operational dates and the programme for trials.

Preparation for modernisation, long refit, etc.

As already remarked, ships undergoing long or special refits are reduced to long-refit-procedure complement and those undergoing modernisation or conversion are paid off into dockyard control. Before paying off or reducing complement, typical preparations required would include the following:

1. Emptying and cleaning out of fuel and other tanks.
2. Landing and returning to store all ammunition, explosives, armament stores, naval stores and victualling stores, whether in the storerooms or issued on permanent loan.
3. Removing all W/T and radar equipment, except the aerials, and returning it to store.
4. Preparing all spare gear and readily portable fittings for storage and placing them in a ship's lock-up (or lay-apart) store on shore.
5. Checking the fixture lists with dockyard officers, and clearing the ship's stores accounts.
6. Landing the ship's boats and returning them to the dockyard.
7. Cleaning out all watertight compartments, storerooms and living spaces; cleaning and drying out the bilges; putting all such places in a state of preservation.
8. Putting all auxiliary machinery, and any fittings liable to deteriorate, in a state of preservation.
9. Providing dockyard officers with copies of the latest reports of surveys and tests, and handing over the *Ship's Book* and all *as-fitted* drawings.
10. Ensuring that all surveys, tests and examinations due to be carried out have been entered accordingly in the ship's defect lists.
11. Handing over all the ship's keys to the Captain of the Dockyard; providing Pink and White defect lists.

When all this has been done, the ship is inspected throughout by the dockyard officers in company with the ship's officers; and if the former are satisfied that all the necessary work has been carried out, the ship is paid off and placed under dockyard control.

Typical preparations required before acceptance into the Reserve Fleet are given later in this chapter.

DOCKYARD ORGANISATION

The present system of organisation in the Royal Dockyards is being completely revised (1963). Some dockyards are still run on the old system, some have changed over to the new, while some are in a state of transition. Unless ships' officers are familiar with the division of duties and responsibilities among the

various dockyard officers and their departments, they will not be able to play their part in promoting efficient refits and repairs. The following notes, covering both the old and the new systems, are designed to show the seaman officer to whom he should go for advice when faced with any problem concerning the dockyard.

OLD SYSTEM OF DOCKYARD ORGANISATION

To cover the working of the old system it will perhaps be most convenient for the reader to have a list of the principal officers in the Dockyard, showing the functions of each department; they are as follows:

The *Superintendent of the Dockyard* is a senior naval officer of Rear Admiral's rank, the title of Superintendent being added after his rank, e.g. Admiral Superintendent (A.S.). He is responsible to the Admiralty for administering the dockyard in its entirety in accordance with the instructions laid down in the *Management Code, Vol. I* (B.R. 2101 (1) to (5), and the Command War Plan.

The *Captain of the Dockyard and Queen's Harbour Master* (C.D. & Q.H.M.) is a naval officer of Captain's rank who is deputy to the Admiral Superintendent and acts as his executive officer in all purely naval matters affecting the Dockyard. As Captain of the Dockyard he is responsible for shore galleys, heads, bathrooms and offices for ships refitting, for rigging, salvage, boom defence, moorings, compass swinging, oil dispersal and canvas work. He is responsible for all movements of shipping within the Dockyard and for the provision of brows to ships in tidal waters. He commands all ships paid off into Dockyard control for large repairs, conversion or modernisation, and ships being built. He operates the Port Auxiliary Service, which provides all water transport within the Dockyard Port, i.e. tugs, water boats, lighters, harbour launches, mooring and boom vessels.

To assist him in the above duties he has a naval staff consisting of *Assistant Captain of the Dockyard*, *Mooring and Swinging Officer*, *Captain of the Dockyard* (*Engineer*), *Master Rigger*, *Shipwright Officer* and a *Lieutenant* (*S.D.*) (*Boatswain*). He is also assisted by civilian officers, such as *Master of Shipping*, *Pier Master*, *Boom Defence and Salvage Officer*.

As Queen's Harbour Master he is responsible to the Admiralty and local Commander-in-Chief for the administration of the waters forming the Dockyard Port as provided in the Dockyard Port Regulations Act of 1865. In this capacity he co-ordinates all shipping movements and berthing within the tidal waters of the Port, over which he exercises general navigational supervision, including pilotage. He is assisted in these duties by an *Assistant Queen's Harbour Master* and a *Master of Shipping* and/or a *Senior Pilot* (civilians).

The *Manager, Constructive Department*, (M.C.D.) is a senior member of the Royal Corps of Naval Constructors and is responsible for the construction of ships in the dockyard and for fitting them out with all accommodation, including galleys; bathrooms and storerooms; water services; ventilation arrangements; pumping, flooding and draining arrangements; magazine stowages; boats, derricks, cranes, winches, capstans, anchors and cables; masts and yards; accommodation and other ladders; and similar equipment. He is also responsible for refitting, converting, modernising and repairing ships and their equipment

in these respects; for the supply of floating galleys and of ships' brows in non-tidal waters; the efficient running of the Yard Planning Office and, during refit, of each ship's planning office. The M.C.D. is assisted by a number of civilian officers: *Chief Constructors*, *Constructors*, *Senior Foremen of the Yard*, *Foremen of the Yard*, *Foremen of Trades*, and *Inspectors*, *Draughtsmen*, etc. He is also assisted by the *Boatswain of the Yard*, who is a naval officer in charge of the labourers for cleaning the yard and ships, and of the slingers, stage-makers and erectors in the Constructive Department. In the future dockyard organisation the Boatswain of the Yard will be a civilian officer, though it is unlikely that his title will be changed.

The *Manager*, *Engineering Department*, (M.E.D.) is a senior naval officer who is responsible for the installation and repair of ships' engineering equipment, i.e. main and auxiliary machinery, boilers and remote-control equipment in ships; gun mountings and directors; other gunnery equipment and, in conjunction with the Electrical Department, weapon control systems; torpedo tubes, torpedoes and other underwater warfare equipment; and ventilation in machinery spaces. He is also responsible for the maintenance of yard machinery, including dock pumps, cranes and air compressors, and for machinery in naval shore establishments. The M.E.D. is assisted by a number of naval engineer officers of Commander's and Lieutenant-Commander's rank, and by civilian *Engineer Officers*, *Senior Foremen of the Engineering Branch*, *Foremen*, and *Inspectors*.

The *Electrical Engineering Manager* (E.E.M.) is a senior naval or civilian officer who is responsible for the dockyard work carried out by his department on the electrical, radio, radar and weapon-control installations of ships undergoing refit or repair. He is responsible for the electrical shore installation in the dockyard. The E.E.M. is assisted by naval and civilian officers such as Commanders (Eng. L.), *Electrical Engineers*, Lieutenant-Commanders (Eng. L.), *Foremen of the Electrical Branch* and *Inspectors*.

Yard Planning Office. This is manned by representatives of M.C.D., M.E.D. and E.E.M. It is responsible for co-ordinating departmental requirements for dockyard programmes, pre-refit planning and ship movements and for certain aspects of financial control and labour allocations.

The *Manager*, *Navy Works*, (M.N.W.) is a senior civilian officer (a civil engineer) who is responsible for the maintenance of all buildings, for shore construction in yards and shore establishments, including basins, jetties, wharves, sea walls, graving docks, roads, railways, etc. and for electrical and mechanical installations in shore establishments; he also carries out land surveys and dredging and arranges the supply of water. The M.N.W. is assisted by civilian officers, such as *Civil*, *Mechanical* and *Electrical Engineers*, *Land* and *Quantity Surveyors*, and *Foremen of Works*.

The *Superintending Naval Store Officer* (S.N.S.O.) is a senior civilian officer who is responsible for obtaining, storing and supplying all naval stores, including oil fuel, lubricating oil and coal, for dockyard departments, ships and naval shore establishments. He is also responsible for motor transport, is the local agent for Royal Fleet Auxiliaries and arranges the carriage by road, rail, sea or air of naval stores and equipment. The S.N.S.O. also provides a delivery service for naval stores and incoming consignments to ships and other departments, and sets up *retail stores* on ships and in the dockyard where naval or

civilian personnel may draw minor items of consumable stores for use when ships are refitting. The S.N.S.O. is assisted by civilian officers, such as *Naval Store Officers*, *Deputy Naval Store Officers*, *Surveyors of Stores*, *Foremen of Storehouses*, and *Inspectors of Storehousemen.*

Any enquiries about sea stores should be made initially to the Warrant (or Issue Control) Division of the Naval Store Department.

The *Finance Manager* (F.M.) is a civilian officer who is responsible for accounting for all expenditure in the dockyard, for recording all work done in the dockyard, and for compiling returns of expenditure as required by the regulations; his assistant responsible for this section is the *Cost Accounts Officer*. The F.M. is also responsible for the payment of salaries and wages of all civilian officers and men of the dockyard; his assistant responsible for this section is the *Cashier*.

The *Superintendent Armament Supply Officer* (S.A.S.O.) is a civilian officer who is responsible for the storage and supply of gunnery and T.A.S. stores, including guns, weapons, ammunition and explosives of all kinds.

The *Superintendent Victualling Store Officer* (S.V.S.O.) is a civilian officer who is responsible for the storage and supply of all victualling stores, including provisions, all types of clothing, medical dressings and mess gear.

Dockyard labour force

For the naval officer to be able to understand and solve the day-to-day problems which beset all ships undergoing refit, it is necessary for him to have a sound knowledge of the composition of the personnel employed in the Royal Dockyards. It is all too easy, through ignorance, for example, to think of a Foreman of the Yard as being equivalent to a petty officer, when he is in fact a very experienced professional officer having control of a large and varied labour force.

Dockyard personnel are divided into two distinct groups, *industrial* and *non-industrial.* In general, industrial labour is that which is actively employed in the repair, refitting, or building of ships, and comprises chargemen, all tradesmen, labourers, and all personnel other than non-industrials. The non-industrial staff comprises civilian officers, from Inspectors of Trades upwards, clerical staff, draughtsmen, etc.

NEW SYSTEM OF DOCKYARD ORGANISATION

Reason for change

Arising from the recommendations of the Admiralty Material Requirements Committee, it was decided in 1958 that the present form of *departmental* organisation of H.M. Dockyards should be abolished in favour of a *functional* organisation. The managers of the functional departments would be under the direction of a General Manager who, under the authority and general direction of the Admiral Superintendent, would be responsible with full authority for the administration and organisation of the productive work of the dockyard, for the control and supervision of its personnel and for the work carried out.

Pilot scheme, H.M. Dockyard, Chatham

The new functional organisation was initiated by introducing a pilot scheme at H.M. Dockyard, Chatham. By 1962 the scheme there was almost fully in operation, the transfer of the various departments to functional units, each under the control of a manager, having been completed.

General Manager's departments—brief description

Planning Department comprises three main divisions, with responsibilities as follows:

1. *Yard Planning Division*, for developing the programme of work for the Yard, preparation of estimates and working budgets for projects.
2. *Planning and Estimating Division*, for all planning action before a refit, modernisation or conversion, including pre-refit inspection visits to ships, ordering equipment and special materials, work acceptance and issue of job orders to Production Department, defining broadly the work on defects and Alterations and Additions which is authorised to be undertaken.
3. *Design Division*, which is an amalgamation of the ship drawing offices of the old Constructive, Engineering and Electrical Departments. It is responsible for the preparation of drawings in conjunction with the Admiralty design departments.

The co-ordination of preparations for a refit, modernisation or conversion is vested in a Project Officer within the Planning and Estimating Division.

Production Department undertakes execution of work authorised for new construction, modernisation, conversion and refit of ships in the dockyard, together with associated repairs of equipment.

This department comprises the working and supervisory force employed on ship work, manufactures, etc. It comprises Constructive, Engineering and Electrical Trade Divisions, closely equivalent to the production units of the original departments, together with a Control Division for preparation of schedules and for the general administration within the Production Department. Provision is made for improved control of trades and for working-level planning by the institution of Trade Offices in each Trade Division, all of which work on a common planning procedure. The re-organisation will ultimately provide a Ship Superintendent, whose function will be to co-ordinate all the work on board a ship and to whom ships' officers can refer their queries.

Personnel Department advises the General Manager on personnel policy and all aspects of personnel management. The Personnel Department, in association with the departments concerned, handles matters of entry, discharge, establishment, industrial and management training, selection and advancement.

The Personnel Manager advises the Admiral Superintendent on general personnel matters; and on such matters his department is accessible to those departments outside the General Manager's organisation.

The Welfare Officers of the dockyard have become members of the Employee Services Division of the Personnel Department, which also houses and provides facilities for the Safety Officer.

Yard Services Department deals with the supply and distribution throughout the dockyard of electricity, compressed air, steam and demineralised water. It

operates the laundry, oxygen plant, telephone system, dock pumps, and mobile and dockside cranes, and undertakes Yard clearance and cleaning services. It supplies electricity, telephone services, steam and air to ships alongside and also provides brows and mobile galleys. It provides a comprehensive plant service to the General Manager's departments, including design, specification, procurement and maintenance of all machine tools, machinery and Vote 8 installations in the dockyard.

Finance Department embraces the previous Cashier's and Cost Accounts Officer's Departments. In general, the Finance Manager is responsible for those functions hitherto undertaken by the Cashier and Cost Accounts Officer, but in his particular responsibility to the General Manager he is to develop Cost Accounting and other data as a means of improving financial control and productivity.

Aims and advantages

The aim of reorganisation in dockyards is to effect improvement of Yard efficiency by the adoption of modern production planning and control techniques in all phases of dockyard work. Limited improvements could be achieved without changing the old departmental structure, but the full benefits of production planning and control systems can only be obtained by changing to a functional organisation. The change will eventually simplify the control and the co-ordination of the labour force and free the direct-production-line officials from many duties which now distract them from the control and supervision of their workmen and their work.

MAINTENANCE ORGANISATION

As already explained, the task of maintenance between refits falls mainly on the ship's staff, and the system of preventive upkeep by means of maintenance schedules, with the bring-up and planning system, has been summarised earlier in this chapter. While every ship must necessarily differ in the details of its maintenance organisation, the following notes emphasise the basic features which experience has shown to be essential. Their practical application, so far as ship husbandry is concerned, is given in the relevant chapter of Volume II.

Chain of command

A clear-cut chain of command (or control) must be established, so that each man knows to whom he is responsible for his work. There must be one officer or rating in each department (or self-contained section) who is in sole charge of the maintenance work. All relevant factors must be reported to him and he must accept all commitments for work and allocate men to jobs. This controller, however, should not be the head of the department. The latter should be free to supervise the department generally and to deal with policy and matters affecting other departments.

Planning maintenance work

The bring-up and planning system should be made flexible and the cards used to record supplementary information that will help in planning, e.g.

whether a particular job can be done at sea or in harbour, and the time, labour and materials required for it. Additional duties of maintainer personnel, such as watchkeeping, must be taken account of, so that the plan for work becomes comprehensive and is arranged so as to show what each man is doing at a particular time and when he will be available for another job. So long as such planning is kept flexible, it will enable the best use to be made of man power and will prevent time being wasted in waiting for jobs to be allocated, or in doing low-priority jobs when high-priority ones are waiting to be done.

Maintenance periods

Certain periods (preferably consisting of a number of consecutive days) in harbour must be allowed at regular intervals in the ship's programme for maintenance. It must be realised that at the beginning and end of these periods some time will be unproductive because of having to allow machinery to cool, for example, and for raising steam and final tests and trials. Therefore the longer the period the greater will be the proportion of it that is effective for maintenance. When leave is given during a maintenance period, the period must be lengthened so that an effort equivalent to that of the whole ship's company during a normal maintenance period is available.

Maintenance support

Ships of cruiser size and above are entirely self-maintaining between normal refits; but smaller ships require some degree of external maintenance support. Each small ship usually has one maintenance period, with support, each quarter, and this is planned often to coincide with an intermediate docking. The maintenance support, in the form of skilled and unskilled man power, main services such as electric power, and workshop facilities, is provided by Escort Maintenance ships, Depot ships, shore bases and Fleet Maintenance units.

Escort Maintenance ships. The primary task of these ships is to help escorts (e.g. frigates) during their maintenance periods with major long-term items in their maintenance schedules, and to make good running defects.

Depot ships. These ships perform the same function as Escort Maintenance ships but for submarines, minesweepers and smaller craft. They also provide accommodation for crews and administrative assistance generally.

Shore bases can supply maintenance support when necessary on the same lines as above.

Fleet Maintenance units. These are shore-based units in the Home ports to provide frigates and destroyers with maintenance support during their quarterly maintenance periods, and also during their normal refits.

SHIPS IN RESERVE

ORGANISATION OF RESERVE

Classes of Reserve

In peace, when it is not possible or desirable to maintain all ships in full commission, those not required for the active fleet are normally laid up in one of the following three classes of reserve:

1. *Operational Reserve*, consisting of those ships and craft which, it is planned, shall be brought forward for service on mobilisation at the highest priority. These ships are kept fully maintained, and are docked and refitted periodically. Except for charts, explosives and some perishable, inflammable and valuable stores, all naval stores and equipment are kept on board. In normal circumstances their notice for sea will not be less than seven days.
2. *Supplementary Reserve*, consisting of ships and craft which, it is planned, shall be brought forward in an emergency, but which have a lower priority than the Operational Reserve. They are kept maintained in their existing state, are docked as necessary, but are not normally refitted. Except for some perishable, inflammable and valuable stores, all naval stores are kept on board. Their notice for sea will not normally exceed twenty-eight days.
3. *Extended Reserve*, consisting of ships and craft of the lowest priority, which are usually de-stored and stripped of portable fittings and of equipment that may be required for other services. They are laid up without maintenance. Ships approved for disposal by scrap, sale or other means are normally included in this class.

Most ships and craft laid up in reserve in the United Kingdom are part of the Reserve Fleet, which is administered by a Commodore.

Preparation for Reserve

Full details of the action required of a ship ordered to reduce to reserve are contained in *Reserve Fleet General Orders*. The requirements vary with the class of ship and the class of reserve, but it is usual for the following tasks to be undertaken by the ship's company before the ship is paid off:

1. Comprehensive trials while power is available, including a full-power trial, to enable an up-to-date defect list to be compiled.
2. De-storing of the ship if required.
3. First-aid preservation of machinery and equipment. For Operational Reserve ships this is limited to that amount of preservation that is necessary to arrest deterioration until the fuller preservation mentioned below can be done.
4. Scrutinising and bringing up to date all papers, documents, records, keys, etc.

PRESERVATION OF SHIPS IN RESERVE

Whenever practicable, ships and craft which have been in service are refitted immediately before being laid up in Operational Reserve. They are then 'preserved' by a dockyard or by civilian contractors. In addition to the more obvious methods of preservation, such as the draining and drying-out of pipe systems and compartments, the cleaning and painting of the structure and fixed fittings, and the cleaning and greasing of equipment and moving fittings, the methods of preservation outlined below may be used.

Packaging

Koonkoting. Working equipment on weather decks, such as the armament and upper deck machinery, is covered overall with netting, which is then sprayed

with plastic to make the package airtight. The humidity inside the package is reduced by including a dessicant. The actual relative humidity at any time can be read through a window in the package.

Monedable wrapping is put round small items of equipment such as bridge instruments and junction boxes. This is a buckram fabric made fairly watertight by a wax or bitumen coating and secured round the item with adhesive tape; dessicants can be included in the wrapping.

De-humidification

As many compartments as possible are sealed off from the atmosphere to form a citadel. Dry air is then kept in continuous circulation around the citadel, the relative humidity being maintained at between 40 and 45 per cent. This should prevent the deterioration of all metallic structure and fittings without unduly drying out the woodwork within the citadel.

Cathodic protection

This is applied to prevent electrolytic corrosion of the underwater hull of a steel ship. It is achieved by passing a continuous electric current through anodes which are slung over the ships' sides.

Wooden craft

The hull maintenance of craft of wooden or composite construction presents particular problems because of the damage that can be caused by dry rot, fungus diseases and marine boring worm. Whenever possible, these craft are laid up ashore under cover. When they have to be laid up afloat in the open, an overall wood and asbestos canopy is fitted; this keeps the craft reasonably dry in all weathers and permits all hatches and doors to be left open to ensure the good ventilation that is so essential to prevent dry rot and fungus disease.

FITTINGS AND STORES

While there can be no exact dividing line between the *fittings* and *stores* of one of H.M. ships, what is meant generally by these expressions is as follows. The fittings comprise the equipment or gear which is an integral part of the ship, has been made expressly for her and is fixed or kept in a more or less permanent position or stowage. Stores consist mainly of things of a standard type which can be supplied to any ship for her general running and maintenance. The following notes are intended to give the seaman officer an outline of the whole organisation for fittings and stores.

FITTINGS

Fittings can be subdivided into *ship's fittings* and *portable fittings*.

Ship's fittings comprise items which are built into the ship or are integral parts of her, examples being: the armament; pumps, fans and other auxiliary machinery; masts and yards; propellers and rudder; capstans, winches and

bollards; and boat booms. No accounts are kept for such equipment, and it is not taken on charge by the ship's officers.

Portable fittings are either portable or can readily be made so, and they are divided into the four following categories:

1. Fittings which are made for a particular ship and which, therefore, are not interchangeable with other ships, examples being: ship's badges, running rigging, awnings and other canvas gear, slings, and fitted furniture not classed as *naval stores* (i.e. stores listed in the *Rate Book of Naval Stores*).
2. Fittings which may be interchangeable with other ships, but which, though of a standard nature, are not classed as naval stores, examples being: flag, cushion, and bread lockers; rifle racks; ventilators.
3. Spare parts of machinery, including small spares, which have not been standardised as naval store articles. These are usually known by the term *spare gear*.
4. Certain fittings which are classed as naval stores and which, though fitted in place, can be made portable. Examples are radio sets, switches and other standard electrical fittings.

All these items must be accounted for and taken on charge by those ship's officers who are chiefly concerned with their use and maintenance. Lists of portable fittings and spare gear are therefore prepared by the main contractors, in conjunction with Admiralty overseers (or dockyard officers) and ship's officers, under the six following heads: Boatswain, Gunner (G), Gunner (T.A.S.), Engineer, Shipwright, and Electrical Officer. Each comprises a list of the fittings and gear with which that officer is charged, a memorandum of instructions, an index and a list of drawings, all bound together in a cover.

Three copies of each list are prepared, and after each has been signed by the officers concerned, two copies are retained in the ship and one is returned to the dockyard for retention by the professional officer concerned.

STORES

Stores are classified under these seven main headings: *naval stores; armament stores; victualling stores; stationery, books and forms; medical stores; hydrographic supplies;* and *canteen stores*. Separate regulations govern the issue, provision, accounting, maintenance and return of each main class of stores.

NAVAL STORES

The term 'naval stores' includes all standard items of an established pattern which are in general use for the work or upkeep of a ship. They are catalogued in B.R.810, *Rate Book of Naval Stores*, which is an authorised list and a priced index of naval stores, and the regulations governing their procurement, accounting, etc. are to be found in B.R.4, *Naval Storekeeping Manual.*

For cataloguing, accounting and indexing purposes naval stores are classified in the Rate Book under the following seven main classes, each of which is designated by four numerals in order to facilitate the use of automatic data

processing and punched card procedures. Each class, except 0100, is subdivided into a number of groups, whose identity is usually conferred by the last two of the four numerals.

Class	*Description of Stores*
0100	Timber and timber materials
0211–0285	Metals and metal articles
0310–0350	Textiles, such as canvas, flags and cordage
0411–0477	Miscellaneous articles, such as rubber, furniture and paint
0511–0641	Electrical stores, including W/T, sonar and radar equipment
0711–0731	Oil fuel, coal and coke for fleet and dockyard services
0811–0824	M/T vehicles and their accessories, and bicycles.

Each item of naval stores is normally given a specified pattern number to enable it to be positively identified, and when such stores are demanded, returned or otherwise referred to, the correct class, group, pattern number and description, as shown in the *Rate Book*, should always be quoted.

Naval stores are generally also classified under the two following categories:

1. *permanent stores*, which have a reasonably long life, are not consumed or destroyed in normal use, and are sufficiently valuable to be completely accounted for;
2. *consumable stores*, which are consumed or destroyed in use within a limited period, or are of such low value that they need not be completely accounted for.

Sea stores

Naval stores issued to ships are accounted for either as portable fittings or as *sea stores*. The allowances of sea stores to various ships are shown in *Allowance Lists of Naval Stores* or, for certain older ships, in *Establishments of Sea Stores*, which are Books of Reference. Such allowances may be fixed in quantity, or they may be scale allowances, where the quantity to be embarked depends upon certain features of the ship. In the latter case, the actual quantity allowed to a particular ship is calculated from information obtained about its permanent features.

Certain sea stores are sub-classified as *first-fitting* (FF), *fitted* (F), or *navigational and trial* (N) stores.

First-fitting stores comprise the anchors and cables, together with their associated gear; and boats and liferafts. These are usually sent to the ship when she is in an advanced stage of construction. The repair or replacement of such stores constitutes a defect which should be recorded in the Pink Defect List.

Fitted stores are those which, though fitted in certain positions in the ship, are readily portable—fire appliances, for example—and they should not be confused with the 'portable fittings' already described. Fitted stores are usually sent to the ship and fitted in place while she is being built.

Navigational and trial stores are those which are necessary to enable the ship to put to sea before the main bulk of stores is embarked (e.g. for trials).

Accounting procedure

Full particulars of all permanent and consumable sea stores issued to a ship are entered by the Superintending Naval Store Officer of the storing yard concerned in two types of loose-leaf ledger, one for permanent stores and the other for consumable stores. These ledgers are then handed to the ship's Supply Officer as a record of all the stores on his charge. Subsequently, those permanent sea stores which are not stowed in storerooms are taken on charge by certain authorised officers or senior ratings of the ship chiefly concerned with their use and maintenance; and for this purpose the ship's Supply Officer prepares and issues lists of such stores (known as *Permanent Loan Records*) to these officers and ratings.

Issue of consumable stores

Quantities of consumable stores to be embarked by ships on first commissioning or after having been de-stored, are shown in *Allowance Lists of Naval Stores*, or, for certain older ships, in *First Outfit Schedules of Consumable Naval Stores*; but these quantities are adjusted by the ship, as experience of usage is gained, to accord with past expenditure and expected requirements. For certain ranges of consumable stores a *valuation allowance* system is operated, under which the Engineering Department, the Air Department (of a carrier) and the remaining departments as a whole are each allowed specified twelve-monthly monetary allowances to expend on each of the following general categories of stores for maintenance and cleanliness:

Paint and paint materials
Cleaning rags
Other cleaning gear
Electric lamps for space lighting
and general illumination only
Timber.

This system allows considerable latitude in the choice and quantity of stores needed to achieve a high standard of smartness throughout the ship.

The twelve-monthly monetary allowances for each department in each class of ship are given in Appendix I to the *Naval Storekeeping Manual.* Every month the Supply Officer of the ship provides each head of a department with details of the value of consumable stores issued to his department during the previous month. These valuation allowances are not intended to cover the expenditure of stores on repair work or refitting by dockyards, for which special allowances of stores are made.

Stocktaking

Stocktaking in a ship is a continuous procedure, organised so that all the sea stores in the charge of the Supply Officer are subject to stocktaking every eighteen months. Differences found are reported at six-monthly intervals.

Musters

The Permanent Loan Records of stores on charge to Departmental Officers are divided into Parts I, II and III. Part I consists of victualling stores. Part III comprises stores normally rigged or secured in place and certain portable sea-

store equipments which are mustered on change of custodian. Part II embraces all remaining stores, including valuable and attractive items such as binoculars and stop watches. Each custodian musters all the stores listed in Parts I and II of his loan record every six months. The stores on loan are also mustered, and signed for in the record, when issued originally and on change of custodian.

Storing periods and intervals

Carriers and Depot, Maintenance and Repair ships are stored initially for a period of six months. The interval between successive replenishments of stores is usually four months, while the corresponding periods for cruisers are five months and three months; in both cases the minimum stock to be maintained is usually equivalent to two months' issue at full-commission rates of expenditure. The comparable figures for destroyers and frigates are three and two months, with one month's issue as minimum stock. Smaller vessels store for varying shorter periods and normally maintain stocks of at least one month's expected expenditure, replenishing at more frequent intervals.

ARMAMENT STORES

The descriptions and quantities of gunnery and T.A.S. stores allowed to carriers and to R.N. Air Stations are given in the *Proportion Book of Naval Armament Stores*, which is somewhat similar to the *Allowance Lists of Naval Stores* already mentioned. For smaller units of the Fleet this information is contained in the *Warrant of Naval Armament (Gunnery) Stores* and the *Warrant of Naval Armament (T.A.S.) Stores.*

Gunnery stores

This term includes: portable weapons and spares for the fixed armament of the ship, e.g. gun barrels and breech blocks; small arms, e.g. rifles, revolvers, and associated equipment; and all ammunition and other explosives such as pyrotechnics. Types and quantities of gunnery stores comprising a ship's outfit are listed in the *Warrant of Naval Armament (Gunnery) Stores*. Their issue, stowage, maintenance and return are governed by the *Naval Magazine and Explosives Regulations*, the *Naval Cordite Regulations* and the *Naval Armament Store Accounting Regulations*. Gunnery stores are usually accounted for by a Lieutenant or Sub-Lieutenant (Special Duties) (G), who keeps the accounts in a special ledger.

Ammunition and explosives not required for immediate use are stowed in the magazines and shell rooms. Small arms, portable weapons, and spares for the fixed armament are stowed in fixed stowages around the ship. Other items are usually stowed in the Gunner's Store. Special precautions are taken to ensure the safe custody of small arms and portable weapons.

Representative samples of ammunition and other explosives are landed for examination and proof as required by the regulations, and the complete ship's outfit of ammunition and explosives is landed periodically at a Naval Armament Depot for examination.

Torpedo and anti-submarine (T.A.S.) stores

This term includes all underwater weapons and equipment for attack and for defence against attack, e.g. torpedoes, ahead-throwing missiles, mines, minesweeping gear and demolition stores.

Types and quantities of T.A.S. stores comprising a ship's outfit are listed in the *Warrant of Naval Armament (T.A.S.) Stores*. Their issue, stowage, maintenance, return and accounting are governed in the same way as gunnery stores; the differences being that the Accounting Officer (when one is borne) is a Lieutenant or Sub-Lieutenant (Special Duties) (T.A.S.) and the accounting is recorded in the *Naval Armament (T.A.S.) Stores Ledger*.

Torpedo warheads are usually stowed in the *warhead room*. Mines are stowed on the mining deck of minelayers. Other T.A.S. equipment is stowed either in fixed stowages around the ship or in the T.A.S. Gunner's Store.

VICTUALLING STORES

The term 'victualling stores' covers a wide variety of items, many of which are not usually associated with the word 'victuals' as applied in its normal sense to mean food and drink. The different victualling stores for H.M. ships are listed below.

Provisions, which are subdivided into *fresh provisions*—e.g. fresh fruit, fresh vegetables, frozen meat and dairy produce—and *dry provisions*, which comprise a wide range of tinned and bagged foodstuffs, as well as rum and vinegar.

Clothing, which includes articles of kit and items such as hammocks, kit bags, attaché cases, suitcases and bedding. It is classed generally as *free-issue* clothing, or *loan* clothing, or *cash* clothing. Cash clothing (slops) is normally only carried in ships larger than destroyers, and is kept in a special storeroom called the *slop room*.

Tobacco, i.e. pipe and cigarette tobacco and 'blue line' cigarettes drawn from Service sources.

Mess gear, which comprises everything used for preparing, serving and eating food. These are of three kinds, classified as follows:

Officers' mess traps, for officers' messes and pantries
Mess utensils, for ratings' messes
Implements and galley gear, for all galleys.

Medical comforts, which include special articles of food and drink as prescribed by the Medical Officer for the sick; examples are soup, broths and consumable spirits.

Victualling stores for medical purposes, i.e. bandages, dressings, glassware, etc. (See p. 228.)

The full range of items supplied is set out in B.R.1246, *Rate Book for Victualling Stores*.

Stocks to be carried

In sea-going ships stocks of *fresh provisions* are regulated according to the ship's requirements and to her facilities for keeping fresh provisions in good

condition. The maximum and minimum quantities of *dry provisions* to be maintained in different classes of ships are laid down in B.R. 93, *Victualling Manual*, which also gives instructions for the issue, inspection, stowage and return of victualling stores. A limited reserve stock of permanent *mess gear* is held on board for replacement purposes and a stock of consumable items related to the available storage and expected rate of use. Under normal conditions of service the stock of *cash clothing* held for sale should not exceed three months' average requirements. The stock of *loan clothing* items is specified in scales set out in the *Victualling Manual.*

Stocktaking and musters

As for naval stores, stocktaking is intended to check the quantities and the condition of each item remaining in store; musters are checks of those issued on loan. The intervals between stocktaking and musters of victualling stores vary according to the type of stores and whether the ship is a tender to a base or parent ship or is self-accounting. Full details are given in B.R.96, *Stores Accounting Instructions.*

STATIONERY, BOOKS AND FORMS

In addition to stationery, such as paper, pens, pencils, ink and notebooks, this term includes stationery for school use, files and filing cabinets, and office machinery such as duplicators, calculating machines, photo-copying apparatus and printing presses; but it does not include 'Admiralty Established Forms' and 'Books of Reference' (B.R.s).

Stationery which could be classed as permanent stores, such as typewriters, filing cabinets and office machinery, is taken on charge by the ship's Supply Officer, entered in the ledger in the same manner as permanent naval stores, and then issued to individual officers on permanent loan.

The scales of stationery for H.M. ships are based on the number of persons doing clerical work, the type of ship and the duties on which she is engaged. Details of these scales, and leaflets giving particulars of 'commissioning sets' for various classes of ship, can be obtained from the Keeper of Stationery and Printing, Admiralty Offices, London, S.W.6. The establishment of typewriters and duplicators for all classes of ships is published in *Admiralty Fleet Orders.* In the first instance sea-going ships are issued with a commissioning set of office stationery sufficient for six months. Thereafter demands for the replenishment of stationery stocks should be forwarded on Form S.1310 to the Keeper of Stationery and Printing at intervals of six months.

The list and scales of allowances of Books of Reference (B.R.s) for H.M. ships is given in the catalogue B.R.1, which also gives detailed instructions regarding their issue, custody and return. On commissioning, ships are supplied, without demand, with a complete set of the B.R.s to which they are entitled, by the Military Branch (Books Section), Kidbrooke, London, S.E.3.

Lists, allowances and full instructions regarding the issue, custody and return of Confidential Books (C.B.s) are given in B.R.150. On commissioning, a ship is issued with a complete set of the C.B.s to which she is entitled by

the Commander-in-Chief or other administrative authority of the port where she commissions.

Lists and allowances of Established Forms (i.e. printed forms for issue to H.M. ships and commonly called 'S Forms') are given in Forms S-1 and S-1a. On commissioning, ships are supplied (without demand) with a complete set of forms sufficient to last the whole commission. Instructions regarding the issue, demand and transfer of S Forms are given in Form S-1.

MEDICAL STORES

The broad definition *medical stores* includes medicines, etc., surgical instruments, dressings and equipment for medical and dental purposes. These items are held on board ship in the charge of the Medical and Dental Officers as appropriate. Where a Dental Officer is not borne the Medical Officer has charge of such dental stores as are carried. Similarly the Squadron Medical Officer is responsible where no Medical Officer is included in a ship's complement, except that the Commanding Officer acts in that capacity when the ship is an independent command.

The regulations governing procurement, accounting, etc. are in B.R.1991, *Instructions for the Royal Navy Medical Service*; B.R.888, *Handbook of the R.N. Sick Berth Staff*; and B.R.888D, *Handbook for R.N. Dental Surgery Assistants.*

Scales and quantities

The scales of medical stores allowed to a ship depend mainly on the complement, station and whether a Medical or Dental Officer is borne. Details are given in B.R.1232, *Scales of Medicines, Instruments, etc. for Service Afloat* and B.R.1852, *Schedule and Scales of Dental Stores.*

The quantities laid down are based generally on six months' estimated requirements and represent the first outfits supplied to new-construction or other ships on commissioning. The scales are not inflexible, being amended from time to time in the light of experience as to the requirements of Medical and Dental Officers and according to changing practices and modern techniques, and consideration is given to reasoned demands for additional quantities or types of stores.

Sources of supply. Medical and dental stores are obtained from three different sources, as follows:

Medical and dental stores (medicines, instruments, etc.)—from a Medical Store Depot.

Victualling stores for medical and dental services (dressings, etc.)—from the nearest Victualling Yard.

Naval stores for medical and dental services (utensils, etc.)—through the Supply Officer of the ship.

Demands for the first-mentioned category are lodged with the *nearest* Naval Medical Depot or R.N. Hospital incorporating a medical store depot, in respect of medical items; but dental items are demanded on the Command Dental Surgeon.

Accounting and stocktaking

Ships' accounts for medical and victualling items are commonly in the form of annual accounts which are rendered to the Medical Director-General at Admiralty (for inspection by the Director of Victualling also, as applicable). These accounts are closed by a stocktaking and survey of the stores held on board and are rendered prematurely on supersession, death or departure of the responsible Medical, Dental, Squadron or Commanding Officer or when the ship is paid off.

Alternatively, where the range of stores is substantial—as where several clinics, theatres, etc. are concerned (e.g. in the largest ships)—or the facility for expansion of the account is desired, a loose-leaf, continuous ledger is maintained. Under this system stores are surveyed whenever necessary and stocktaking reports have to be sent to Admiralty covering the entire range of stores, annually for medical items and every 18 months for victualling items.

Under both systems the permanent naval stores are accounted for on loan lists from the Supply Officer. Consumable naval stores are off charge when issued by him.

HYDROGRAPHIC SUPPLIES

This term covers the charts, air charts, maps, books, publications and timepieces provided for the navigation of the Fleet.

The Admiralty Charts and Hydrographic Publications are compiled by the Hydrographic Department, Admiralty, and their distribution, together with that of other navigational and meteorological publications, chronometers and watches which usually accompany the charts, is arranged by the Admiralty Hydrographic Supplies Establishment, Creechbarrow House, Taunton, Somerset. Correspondence from ships and establishments should be addressed accordingly.

Admiralty Chart and Chronometer Depots are established at various ports at home and abroad, details of which will be found in Hydrographic Publication H.51. Initial supply of navigational chart outfits and timepieces will normally be made from a Chart Depot. Arrangements for subsequent replenishment and correctional matter are made by the Hydrographic Supplies Establishment.

Chronometers and watches

First supply is usually made from the Chart and Chronometer Depot issuing the chart outfit. The main Chronometer Department is at the Royal Observatory, Herstmonceux, Sussex, but all correspondence relating to chronometers and watches should be addressed to the Hydrographic Supplies Establishment, Taunton. Replacements at home should normally be arranged through Taunton, but urgent requirements and requirements abroad may be effected through the nearest Chart and Chronometer Depot.

Full details of the methods of supply and correction of chart outfits and about navigational timepieces are contained in Hydrographic Publication H.51, *Hydrographic Supplies Handbook*, and they are also referred to in B.R.45(1), *Admiralty Manual of Navigation*, Vol. I.

CANTEEN STORES

These are the property of the Navy, Army and Air Force Institute, and their provision, custody and accounting are the responsibilities of the ship's Canteen Manager and officials of the Institute. They are stowed apart from Government stores in the ship's canteen and in store rooms specially allocated to them. Ship's officers have no responsibilities in regard to canteen stores except those of providing reasonable facilities for their issue, care and custody. Apart from the sale of canteen stores to individuals and to messes, they may be purchased by the Ship's Supply Officer to supplement the government ration of food.

PART IV

SHIPHANDLING AND NAVIGATION

CHAPTER 11

Officer of the Watch at Sea

STATUS

The status of the Officer of the Watch is defined in *Q.R. & A.I.*, Chapter 1, as follows: '*Every officer or person under the rank of Captain, not being the Executive Officer or the Commanding Officer for the time being, is to be subordinate to the Officer of the Watch, whatever may be his rank, in regard to the performance of the duties with which the Officer of the Watch is charged.*' At sea the Officer of the Watch is thus the Captain's representative on the bridge. Furthermore, all his responsibilities remain with him whether the Captain is on the bridge or not, unless the Captain has specifically relieved him of them.

A junior officer carries no greater responsibility at any time than when Officer of the Watch, and any suspicion that time spent as such is wasted as compared with any other activities must be dispelled at once. Just as a doctor may be expected to diagnose an emergency case and prescribe the correct treatment in a matter of moments, so an Officer of the Watch may be expected in an emergency to take the correct course of action (and there may be only one) to save the ship and her company from disaster. In both cases, only the most thorough training and full professional background knowledge, coupled with an alert mind, will ensure that the right action is taken at the time.

RESPONSIBILITIES

The chief responsibility of the Officer of the Watch at sea is the safety of the ship, and in particular her safety from collision. Whether or not a qualified Navigating Officer is borne, the Officer of the Watch has a certain responsibility for the ship's safety when approaching land, and in general for keeping himself informed of the position of the ship. He is responsible for keeping the ship in her station, for the steering, for the safety of men on the upperdeck and in exposed positions. He is expressly authorised to alter the course and speed of the ship to avoid immediate danger, but not otherwise without directions from the Captain. All these responsibilities and a number of other ones are laid down in Chapter 31 of *Q.R. & A.I.*, and before learning to be an Officer of the Watch every junior officer must read and thoroughly digest these orders.

KNOWLEDGE REQUIRED

Rule of the Road

An Officer of the Watch cannot fulfil his most important obligation, that of the safety of the ship from collision, without having a *complete* knowledge of the *International Regulations for Preventing Collisions at Sea*. These regulations are printed in Volume II, and also in B.R.45/1, *Admiralty Manual of Navigation*, Vol. I. To know these rules thoroughly may entail learning the principal rules

by heart, and every Officer of the Watch must not only put in some hard work at the beginning of his career on learning the Regulations, but must refresh his knowledge of them at frequent intervals. Captains should devise their own methods for testing the knowledge of their Officers of the Watch. It is an unfortunate fact that incomplete application of the Regulations is a contributory cause in most cases of collision. To put this in another way: if ships obey the rules implicitly they cannot collide with one another.

If yours is the giving-way vessel always remember that by taking action boldly and early you not only make clear your intentions to the other ship, but you prevent both ships from getting into proximity with each other. It is when ships are already at close quarters and danger is present that people may get flustered and make mistakes.

Knowledge of own ship

A professional knowledge of the capabilities of his own ship is essential to the Officer of the Watch. It is impossible to define precisely what is implicit in this, but the following may help:

Construction. The main features of the ship's construction, with particular reference to watertight compartmentation and vulnerability to collision. Her stability, and how it can be altered and controlled. The ship's organisation for control of damage.

Propulsion. The power and speeds obtainable with different arrangements of boilers and/or main propulsion machinery, and how these can be controlled from the bridge. Revolutions required for different speeds. Propeller and rudder arrangements.

Navigation. The aids to navigation fitted in the ship, their capabilities and limitations (particularly their possible errors) and how each can be brought into play and used. These include compasses, sounding equipment, logs, high-definition warning/surface radar, radio aids to navigation. The shiphandling characteristics of the ship, and in particular the effect of wind on her handling qualities.

Steering and conning. The various methods available and how to change over to secondary from primary methods.

Communications. The ship's communications organisation and how it is linked with the bridge. Familiarity with all the tactical and manœuvring signals and instructions appropriate to the ship's current task.

Armament and action. Those weapons which may be brought into action in an emergency by the Officer of the Watch and how to control them. The Action Information Organisation of the ship and how it works, particularly with regard to the surface and underwater situation.

Sources of information

Again, it is impossible to list all the possible sources of information, but the following may give some indication of where or how to improve ship knowledge:

Construction. The fundamental need is for a knowledge of one's own ship, which can only be found by looking, and seeing for oneself. Chapters on warship construction, damage control and stability will be found elsewhere in this manual.

Propulsion. Information is contained in the *Captain's Ship's Book*, the *Navigational Data Book* of the ship, and in Vol. IV of *Admiralty Manual of Navigation*. If in doubt, consult the Engineering Department of the ship.

Navigation. Consult B.R.45, *Admiralty Manual of Navigation*, particularly Volumes I and IV, and ask the Navigating Officer or his assistant to show you how to use any equipment on the bridge.

Steering and conning. Organisation and drills should be given in the Captain's Standing Orders.

Communications. The various tactical and other signal publications must be studied and, when on exercises or operations, the current orders.

Armament and action. Consult the departments concerned (Gunnery, T.A.S. and N.D.) and the technical publications on weapons and A.I.O.

In addition to knowledge of his own ship, the business of being a capable Officer of the Watch will employ a store of learning about many subjects, particularly seamanship, acquired throughout his training and career. In a man-of-war the Officer of the Watch must regard himself as being part of a Command Team, each of whose members has a part to play in the deployment of the ship and her weapons to maximum advantage. Besides the Captain and Officer of the Watch, the other members are the Operations Room Officer, the Navigating Officer and the various controllers of weapon systems.

How to con the ship

Orders for the wheel and engines should always be given clearly, decisively and in the correct terms, in order to avoid any misunderstanding. The correct orders to use are given in Volume I.

Knowledge of the layout of the bridge

Before keeping a sea watch for the first time in any ship an officer should acquaint himself with the layout of the bridge, the position of each instrument, communication system or electric switch, and the tone or noise of the buzzer or call-up on each communication system, so that in the dark he can immediately place his hand on the instrument he requires. Particularly important items are the telephones, voicepipes and intercom systems, the alarm pushes for the lifebuoys, the master switches for the navigation lights and the not-under-command lights, the position and controls of the bridge radar display and the control handles for the whistles (or sirens).

LEAVING HARBOUR

The Officer of the Watch should be on the bridge in sufficient time before the Captain to check that the special sea dutymen are at their stations and that the ship's log and other routine orders and papers have been transferred from aft to their forward site near the bridge. He should have the telephone numbers check their communications with the forecastle and quarterdeck, and should personally check the reading of the Pelorus gyro-repeater with those in the primary and secondary steering positions, and on the wings of the bridge.

The engineering department is responsible for testing the functioning of the main propulsion machinery, the engine-room telegraphs, the steering gear and

the sirens; and also for testing the functioning of the gyro-compass repeaters and all electrical communications.

If the Officer of the Watch is provided with a *special-sea-dutymen check list* that enumerates all the items that must be checked before the ship gets under way, this should help him to make sure that there are no omissions.

Immediately before the ship gets under way the order 'Obey engine-room telegraphs' is passed from bridge to engine room, but only at the direct order of the Captain. When the ship is clear of harbour the Captain will order the special sea dutymen to be relieved by the sea dutymen of the watch.

TAKING OVER A WATCH

It is most important that a watch should be turned over thoroughly and conscientiously. When relieving, you should arrive on the bridge in good time to allow a full briefing, and if at night to allow also for your vision to become adapted. In warships under operational conditions it is customary to stagger the times of take-over for Officer of the Watch, Operations Room and armaments, etc., and not to use the traditional times of watch turn-over. If this is not done, there is an open invitation to a shadowing enemy to make his attack at, say, 0400 precisely, hoping to catch the entire ship in the throes of turning over the watches. Under operational conditions the Officer of the Watch will probably find it useful to visit the Operations Room on his way to the bridge. He can quickly see there from the various plots what is the situation generally, and in particular the positions of all ships in the vicinity.

The relieving officer should insist on covering all the following items, in so far as they apply to the situation, before taking over:

Command situation

The whereabouts of the Captain and any orders of his about the future conduct of the ship in his Night Order Book or elsewhere, and his orders for being called.

Navigation situation

The whereabouts of the Navigating Officer and any orders of his about the navigation or about being called.

Position of the ship on the chart, her intended track, and identification of any land or lights in sight, and details of any expected to be sighted.

Course of the ship by gyro-compass and/or standard compass; any compass errors. Any wheel being carried. Details of zigzag if in force.

Speed ordered and revolutions required for it, or to keep in station.

Engines or boilers connected and maximum speed available.

Depth of water, and any orders about taking soundings.

Navigation lights. To be checked if lit; or, if not, any orders extant about when to switch them on.

Operational situation

Ships. Identity of ships in company, and any other friendly forces expected to join. The task and disposition of the force. Position, course and speed of

any other ships detected or sighted and whether they are expected to pass clear.

Station. The ship's station, the identity and position of the Guide and adjacent ships, and any necessary information about keeping in station. The tactical diameter in use, operational speed and stationing speed.

Communications. The organisation in force for manœuvring signals.

Action Information Organisation in force. Radar, sonar and other transmissions and the policy on their use. Lookouts closed up and their duties.

Internal situation

Ship's company work in progress; men working in exposed positions. State of seaboats, and watch on deck.

Organisation in force for damage control; the watertight condition and ABCD state of the ship and who is in charge of it.

Weather situation

The state and forecast for the weather, and any likelihood of fog. If in fog, the organisation for making sound signals, the method of keeping station, any extra lookouts placed, fog lights in use, and any extraneous fog signals heard or radar contacts detected.

Taking over

Before finally taking over you should check once again that the course ordered is actually being steered and that it is a safe one when laid off on the chart, and that you are fully aware of the presence and movement of any approaching vessels that carry with them the slightest risk of collision. If considerably out of station you should not take over the watch until your predecessor has regained station. When fully satisfied that you can take charge, make it quite clear to your predecessor that you are doing so by saying, for example: 'Right, I will take over now'.

ACTION DURING THE WATCH

Watching

While on watch never forget the significance of the word 'watch'. You should be constantly looking out ahead, and frequently also astern, and should take pride in being the first to spot anything new that comes into view. If you are obliged to leave the place from which you can see out—in order, for example, to look at the chart—make sure that someone else is doing so for you. If navigation lookouts are placed, see that they know the general situation and what especially to look for. The efficiency of lookouts can be greatly improved by the encouragement of the Officer of the Watch; and, conversely, they will become unreliable if ignored. This applies equally to the lifebuoy sentry aft, who should be kept in contact and made aware that he is the astern lookout.

As soon as you sight another ship for the first time TAKE A BEARING of her. Watch the movement of the bearing and continue to do so at intervals until either you are quite sure that she is about to pass well clear or until avoiding action has been taken.

It is a modern mistake to place one's faith implicitly in radar. The human eye can detect a change in the inclination of another ship more rapidly than radar; and radar sets and displays are not always adjusted to produce optimum results. The Officer of the Watch should depend on his own eyes, but should make sure that others extract information from radar and pass it to him, a point which will be referred to again later in this chapter.

Lookouts

In war the chief function of lookouts is to guard against surprise from either air or submarine attack. The duties and stationing of anti-aircraft lookouts are the responsibility of the gunnery department, and those of anti-submarine lookouts the responsibility of the T.A.S. department.

In peace the Officer of the Watch is responsible for any lookouts stationed to assist in the safe conduct of the ship. In a big ship, when the weather is clear, it is customary to place one lookout on each side of the bridge or pilotage position; but in a small ship the signalman on the bridge may be the only lookout by day, although it is customary to have lookouts placed at night. If the visibility is reduced the Officer of the Watch should immediately order additional lookouts. One is placed usually in the eyes of the ship and, if the fog is low-lying, one aloft. As already remarked, the lifebuoy sentry should be employed always as an astern lookout.

Lookouts usually do tricks of 20 minutes. It has been found that even with the most conscientious men results on average cannot be as good if the tricks are any longer. The Officer of the Watch should allocate the arcs which his lookouts are to scan.

Sometimes special lookouts are placed to watch and report to the Action Information Organisation on a particular item—for example, helicopters.

Lookouts should be encouraged to report *everything* which they sight, and should never be told to ignore anything.

Reports to the Captain

The Officer of the Watch is not expected to deal with every situation himself. His function rather is to be the first to become aware of a change developing in the situation and to summon up the people needed to deal with it. The most important person to call upon is the Captain, and the Officer of the Watch should never be afraid to do so. A wise Captain gives clear directions in his Standing Orders as to the circumstances in which he is to be called, and emphasises in them the importance of calling him *if in any doubt whatsoever*. He does not rebuke an inexperienced Officer of the Watch who occasionally calls him on some trivial pretext. Neither the Captain nor the Navigating Officer can obtain any real rest at sea unless they are confident that they will be called (and thoroughly roused) in plenty of time when necessary.

The Captain is usually called on the following occasions:

Navigation situation

1. The detection or sighting of any ship likely to pass within, say, two miles. Failure to observe the Rule of the Road by any vessel that appears to carry the slightest risk of collision.

2. On any alteration of course being made to avoid danger (or for any other reason); and also whenever the Officer of the Watch thinks it likely that an alteration of course will be required for any reason.
3. If being set off course.
4. The detection or sighting of land or navigational marks, or the failure to detect or sight them by the expected time.

Operational situation

1. Any signal ordering or involving a change in speed, course or station; its receipt, execution and the action taken on it.
2. The sighting or detection of any warships other than those presently in company.
3. If own ship or a nearby ship is out of station, or if there is any difficulty in keeping station.

Weather situation. Any change in the weather. It is particularly important to call at night if the weather changes for the worse. The ship's course and speed may need to be adjusted in order to make a certain position on the following morning.

At sunset, with a report (see page 241).

Emergency. Any emergency situation—if possible, as soon as there are any signs that it may develop, rather than when it has already become critical. Various emergencies and the action appropriate to each are described later in this chapter.

Navigation and pilotage

The part played by the Officer of the Watch in the actual navigation and pilotage of a ship depends largely on whether a qualified Navigating Officer is borne, but no matter how small the part he plays he is always responsible for the safety of the ship. He should therefore keep himself informed of the ship's position and keep a check on her navigation or pilotage. No one is infallible and no instrument is absolutely reliable, and a conscientious check by the Officer of the Watch on the navigation and pilotage of the ship is one of the greatest safeguards against a stranding caused by human error or a mechanical fault.

Take every opportunity for checking the compass for error, either by a transit of navigational marks or by a bearing of the sun or a star. The gyro-compasses should be compared with each other and with their repeaters hourly, and also with the standard compass in ships fitted with magnetic compasses.

A check should be kept on the actual course steered by the ship, and if she is yawing or carrying wheel the Officer of the Watch should see that the mean course steered agrees with the course ordered. The mean of the revolutions for each hour should be compared with the revolutions ordered, and the hourly log readings with the speed ordered.

The course laid off on the chart should be checked to ensure that it is a safe one. In pilotage waters every navigational mark should be identified as it comes in sight, and the position of the ship should be fixed at frequent intervals. The Officer of the Watch should know the approximate strength and trend of any

current or tidal stream, and should report immediately if the ship is being set to one side or the other of her intended track. All fixes should be clearly recorded on the chart, and also in either the Officer of the Watch's notebook or the Navigating Officer's notebook. When approaching land the Captain should be asked for instructions about taking soundings and clearing away the anchors and cables.

When in formation with other ships in pilotage waters do not follow the wake of your next ahead blindly, but check the position, course and speed of your own ship and do not hesitate to haul out of line if you think she is running into danger.

Action Information Organisation

All warships have an Action Information Organisation, which is designed to gather in all the available information about ships, aircraft, submarines, etc., both near and far, and to present it quickly in an easily comprehensible form to the Command—that is, to the Admiral or Captain or their staffs. The organisation is centred in specially-equipped compartments having various kinds of plots and displays and is manned by trained personnel. The Officer of the Watch has a duty at all times not only to feed information to the A.I.O., but also to see that it provides him with any information that can help him. He must see, for example, that the Operations Room is supplied from the bridge with up-to-date information about signalled courses, speeds and changes of formation; with visual sightings, and with visual confirmation or contradiction of radar contacts. At the same time, the Officer of the Watch should insist that the A.I.O. tracks every ship as soon as detected and reports to him her course and speed and whether she is expected to pass clear, and, if so, where and when will be her closest point of approach.

Station keeping and changing

The Officer of the Watch is responsible for keeping the ship in her station. He must make it his business to keep *exactly* in station, realising that if he is lax he will not only inconvenience, but may endanger, other ships in company.

Remarks on keeping and changing station are made in Chapter 14. In addition, the Officer of the Watch should be familiar with the relative-velocity problems involved in changing station, and how to use radar to help solve them, as described in *Admiralty Manual of Navigation*, Vol. I. He must also have a first-class knowledge of all the manœuvring and tactical instructions in force in the Fleet.

The watch on deck

The relieving watch or part of the watch on deck should be mustered five or ten minutes before they are due to take over. The Petty Officer of the Watch should then detail them for their watch duties such as lookouts, messengers, lifebuoy sentry and helmsmen. He should then detail the seaboat's crew. If lowerers are required they should be detailed from personnel closed up as weapon crews or elsewhere. He should also make certain that ratings are detailed for such duties as placing emergency navigation lights.

Seaboats

Before he takes over his watch duty, the coxswain of the seaboat should inspect his boat and her gear, reporting on completion to the Officer of the Watch.

When the tactical and armament situation allows, the Officer of the Watch should exercise the manning of the seaboat from time to time and should always ensure that an officer is present at an actual lowering and hoisting. If no officer is available the Captain may direct the Officer of the Watch to leave the bridge to lower and hoist the seaboat.

Sunset

Half an hour before sunset the duty rating from the Electrical Department should test all electrically-operated navigation lights, not-under-command lights and any other special lights and report their state to the Officer of the Watch. The Officer of the Watch must see that the secondary navigation lights also are ready for immediate use if required.

At sunset the Officer of the Watch switches on the navigation lights (unless he has been given orders not to) and reports to the Captain when he has assured himself that they are shining correctly. If the ship is darkened the Officer of the Watch is responsible that no lights show outboard, and he must send men round from time to time to check.

Signals

In the absence of the Communications Officer, the Officer of the Watch should supervise the visual signalling watch. He must make sure that signals from other ships are promptly answered, that no unauthorised signals are made, and that important signals go immediately to those concerned. This applies particularly to the reporting of manœuvring signals to the Captain.

Take any opportunity that arises for ascertaining the names and destinations of passing men-of-war or merchant ships, and conduct signal exercises with any British or foreign merchant ships that are willing to co-operate. Merchant ships should not be called, however, in pilotage waters, because this might distract their Officers of the Watch from looking after the safety of their ships. See that your ensign is dipped promptly in reply to the salute of a passing merchant ship; failure to do so is extremely discourteous.

Looking after the ship

This includes not only preventing the ship and her equipment from being damaged, but also ensuring the safety of men on deck and the comfort of those below and controlling all matters which may affect the ship's routine.

When the ship is in a seaway, keep a careful watch on her behaviour, and if she appears to be labouring take appropriate action before she suffers damage. Remarks on handling ships in rough weather are given in Chapter 15.

Keep an eye on the weather, particularly in the tropics where calm periods may suddenly be broken by heavy rain squalls. The Officer of the Watch should know the employment of the hands on deck and the state of the upper-deck equipment, so that when a squall approaches he can take the appropriate action.

In calm weather, and particularly at meal times, give warning when possible of any sudden alteration of course which will heel the ship. In rough weather warning should be given, when possible, of any alteration of course which will increase the motion of the ship, as when turning broadside on to the sea.

During the night watches, and particularly in rough weather, rounds must be conscientiously carried out both below and above decks every hour or half-hour. Those who go the rounds should look out for leaking hatches or scuttles, the security of equipment (particularly on the weather decks) and any potential fire risks.

Watch the ship's routine and give good warning of any change in it. It is most important to warn heads of departments as early as possible of any changes of the ship's programme, such as an alteration of the time of arrival in harbour.

ACTION IN EMERGENCY

Be prepared!

The Officer of the Watch must always be prepared to take immediate action to save the ship, or some member of her company, on his own initiative. Think about the various emergencies that might happen during your watch, and run over in your mind the various actions that you would have to take and in what order, so as to cope with each situation. Exactly what would you do, for example, if you heard the cry 'Man overboard!'; or if the main engines in the ship ahead in column were suddenly stopped when steaming at 25 knots; or if your ship was surprised by an unseen enemy with, say, torpedo or some other kind of missile attack?

It is not possible to list all the actions required in different abrupt emergencies such as those described. The appropriate action depends on the particular ship's organisation, or on the tactical, operational or exercise orders in force. But unless you have rehearsed the action in your mind, you will be powerless to act promptly. Some elaboration of certain contingencies is given further on in this chapter.

Prevention is better than cure

Unfortunately many occasions requiring drastic and rapid action are allowed to arise quite unnecessarily, through the inattention or lack of foresight of the Officer of the Watch. This applies particularly to crises where danger of collision or grounding materializes apparently without warning. Early action to put the ship on a safe course, or to take the way off her, would have prevented a crisis from developing at all.

Most accidents at sea are caused by one or more of the following omissions or mistakes:

1. failure to take the correct action because of incomplete knowledge of the Rule of the Road;
2. failure to keep a good lookout;
3. failure to take seamanlike precautions in potentially dangerous circumstances such as low visibility, or when steaming without lights;

4. failure to check the ship's position, course and speed frequently;
5. failure to look ahead and realise that, unless some action is taken now, a dangerous situation will arise in the future;
6. indecision and consequent delay until it is too late to save the situation.

If you have read this chapter so far you will know the remedies. Only the most important of these will be stressed once again: that is—if in doubt *call the Captain* and do so *in good time*, so that he can reach the bridge and take the necessary action *before* the situation has become dangerous.

Other information

Some remarks on emergency action when manœuvring in a confined space or when faced with the inevitability of a stranding or a collision are made at the end of Chapter 13. Information about handling ships in heavy weather, such as how to heave-to, is given in Chapter 15.

Watertight integrity

A good insurance against accident is to maintain stringent control over the closing and opening of the watertight doors and hatches of a warship at sea. Whenever a ship is afloat, a watertight condition is ordered which governs the number of watertight openings to be kept closed, i.e. the watertight integrity of the ship. Details of the system are given in Volume I, but the principal points, so far as they affect the Officer of the Watch, are as follows. In time of war the watertight integrity of large ships is controlled from ABCD Headquarters (HQ1), where a continuous watch is kept; but in frigates and smaller ships the watertight integrity of the ship is controlled by the Officer of the Watch in all ABCD States of Readiness other than State 1 (the Action State). In peace, the watertight integrity of cruisers and some larger ships may similarly be controlled by the Officer of the Watch.

The normal watertight condition of a ship in peace is Condition X, but Condition Y should be assumed whenever the ship is entering or leaving harbour, when manœuvring in company, and also in low visibility. In war, Condition Y is the normal condition, but it depends largely on the possibility or probability of attack by the enemy. In emergency, the watertight openings are closed by the order 'Close all Red openings' and a signal on the ship's alarm rattlers, probably in conjunction with the order 'Emergency Stations'.

When the Officer of the Watch is in control of the watertight integrity of the ship he should exercise strict supervision of the opening and closing of doors and hatches, and never allow too many to be opened at a time in any one section of the ship. He should ensure that the necessary entries are made in the *Watertight Integrity Log*, and that these deviations from the watertight condition in force are correctly recorded on the *ABCD Door and Hatch Board*.

When not in control of the watertight integrity of the ship the Officer of the Watch should always know the watertight condition in force, and he should not hesitate to order a higher condition if he considers it necessary in low visibility or in an emergency. But he must realise that a change from one watertight condition to another may require an increase in the State of Readiness in order to obtain the hands necessary for the task.

Gastight integrity

In war and during peacetime exercises, a gastight condition may be superimposed on the watertight condition. The gastight condition governs ventilation arrangements in the ship, i.e. the gastight integrity. The control of gastight integrity goes hand-in-hand with that of watertight integrity and the remarks in the preceding paragraph regarding control are equally valid. In war, Condition B is the normal gastight condition, from which the ship can be completely closed down (Condition A) within 5 minutes.

When the Officer of the Watch is in control of the gastight integrity of the ship he must control strictly the opening-up or working of ventilation systems needed to operate for short periods to make the ship habitable. He should ensure that these deviations from the gastight condition in force are correctly recorded on the *Ventilation Board.*

When not in control of the gastight integrity of the ship, the Officer of the Watch should always know the gastight condition in force, and he should not hesitate to order a higher condition if he considers it necessary—e.g. when there is an increased or immediate threat of encountering nuclear, biological or chemical agents. It should be borne in mind that a change from one gastight condition to another may require an increase in the State of Readiness in order to obtain the hands necessary for the task.

ABCD State of Readiness

This governs the entire material state of the ship (other than doors, hatches and ventilation, which are controlled by the watertight and gastight conditions) and the number of men closed up for ABCD duties. The Officer of the Watch should always know the ABCD state in force and should not hesitate to order a higher state to meet a threat or emergency, or in order to achieve a new watertight or gastight condition rapidly. Remember that a change of state of readiness may take an appreciable time because, although personnel may be closed up quickly, the material preparations and changes of machinery and pipe-system-states may be quite involved.

Steering, conning and propulsion emergencies

Mistakes in passing orders. If the quartermaster or helmsman makes a mistake by putting the engines or wheel to a different setting from the one that you have ordered, you should become aware of this immediately because you should be watching those instruments on the bridge that show what he has done. Do not rebuke him, but urgently repeat the original order very precisely and clearly, calling the quartermaster to the wheel if he is not already there. If the wheel has been put the wrong way it is advisable to order 'Amidships' before repeating the original order. Later on, when the situation is in hand, you may deal with the quartermaster if he or his helmsman caused the mistake through being inattentive. But the best insurance against mistakes is to give your orders so decisively that there is practically no chance of their being misinterpreted.

Breakdowns in steering. A general idea of the different methods of conning and steering H.M. ships is given in Volume I, and more detailed information in B.R.45(4), *Admiralty Manual of Navigation,* Vol. IV. In each individual ship the methods and drills for changing-over steering and conning positions are promulgated in the Captain's or Ship's Standing Orders, and there is usually a

summary available on the bridge. However, if a breakdown occurs the Officer of the Watch must know exactly what to do, and must start giving orders at once. He will only be able to do this if he has made himself familiar with the facilities available at each steering and conning position, and the action needed in each place to effect change-over.

Remember that while the steering control is being changed you will have to try to keep the ship on her course by the use of the engines. Warn the engine room what is going on and be prepared to make radical changes, such as, for example, stopping the starboard engines and increasing speed by 5 or more knots on the port. Hoist the not-under-command signal by day, or switch on the lights by night; and remember your next astern, if in column.

Propulsion machinery breakdown. Certain breakdowns require immediate action to stop the ship or unit concerned (see B.R.45(4)). For example, if lubricating-oil pressure to a turbine, or feed-water supply to a boiler, fails, the propeller shaft concerned has to be stopped or its speed drastically reduced within seconds if serious damage is to be avoided; and this must be done without waiting for permission from the bridge. If this happens to your ship the first essential is to alert ships in company to the fact that something is wrong. The quickest way to do this is by making six short blasts on the siren. You must then show the not-under-command signal, make a warning to the ship astern (if in column) on any suitable communications system, and hoist Flag 5, indicating 'breakdown.' If you decide to turn out of your column, make an alteration of course sufficiently large to clear the line, but not so great that a broad inclination is presented to the ships astern. A turn of 20° to 30° should be enough. Tell the ships astern what you are doing.

If the ship ahead of you in column suffers such a breakdown you must be prepared to take instant and drastic avoiding action as necessary to prevent collision. It is impossible to lay down rules as to how ships should act, because the broken-down ship may be forced out of the line either one way or the other momentarily by the failure of the propulsion on one side of the ship only.

Compass breakdown. Only by being continuously alert, and by comparing the different gyro-compass repeaters and magnetic compasses frequently, will the Officer of the Watch detect quickly a compass failure. If the ship has gone off her course, he must immediately con her back by using a repeater that appears to be reliable, or the magnetic compass. He must also bring into play the organisation for remedying the breakdown, which normally entails, amongst other things, summoning the maintainer rating responsible and informing the Navigating Officer.

Lifebuoys

Ships have lifebuoys (and usually special sea markers as well) placed aft ready for use, with buoyant electric lights fitted. A sentry is stationed by them when at sea, and he has near him an electric gong operated from the bridge, and also a telephone to the bridge. The order to cast overboard one or more lifebuoys is made by working the gong from the bridge. A code may be established to indicate whether both the lifebuoys, or alternatively either the starboard or port one, should be thrown. The sentry should be kept in contact by regular calls on his telephone throughout the watch. He acts as a lookout astern.

Man overboard

Precautions. The Queen's Regulations state that the Officer of the Watch is 'primarily responsible that orders are given to prevent any person going on to the weather decks when the weather is such as to make it dangerous, especially when he is aware that an alteration of course or speed is likely to render the upper deck unsafe'. Thus if a man is washed overboard it may be the fault of the Officer of the Watch. Always make it your business when on watch to see that the ship's company is warned of any impending alteration of course in heavy weather, and that men are forbidden to go on the upper deck when conditions are really bad, or that, if they do, the necessary precautions such as the rigging of lifelines and the wearing of lifejackets are taken.

Action

1. Immediately you hear the call or get the message 'Man overboard', ring the alarm for the lifebuoy sentry to throw his lifebuoys and markers, and if in company make six short blasts on the siren to wake everybody up.
2. If safe to do so, start altering course round towards the man's position (see remarks on shiphandling below).
3. Tell or send a message to the Captain, Executive Officer and sick-bay.
4. Tell the Action Information Organisation, if closed up, to mark the plot.
5. Set lookouts to search for the man in the water.
6. Call away the seaboat's crew (see 'Picking up by boat', page 247).
7. Make any appropriate signals to ships in company.

Shiphandling aspects. If a man falls overboard he will drift aft at 8·3 feet per second for every 5 knots speed of the ship. If, for example, a man falls overboard amidships from a frigate steaming at 20 knots he will be about abreast the propellers in just under 5 seconds. Stopping the engines on the side from which the man fell to prevent him from being drawn into the propeller race will therefore be useless, unless the man falls from right forward in a long ship which is steaming at slow speed, because even at 10 knots it will take at least 10 seconds to stop the propellers from the time the order is received in the engine room.

Under most circumstances it will also be too late to put the wheel over towards the side from which the man fell in the hope of swinging the stern away from him. Besides, there is often doubt at first as to which side the man fell from. Experience has shown that a man will probably float aft clear of the ship's propellers even if no action is taken to avoid him.

The best action to take is to increase speed and start turning with plenty of wheel as soon as it is safe to do so. During the latter stages of the turn the ship can be manœuvred as necessary to bring her up to windward of the man and as nearly as possible beam-on to wind and sea so as to provide a lee for both boat and man. Do not reverse the inner screw at first, because if you do you will probably finish up well in advance of the man (see Chapter 12); and do not slip the seaboat until close to the man.

If you wish to steam back down your track to search for the man, an approximate method of doing so is as follows. Swing out with maximum wheel either to starboard or port, and subsequently reverse the wheel so that the ship's head

swings out to, but not beyond, 60° from the original course; and then continue to swing back with full wheel, finally steadying on the reciprocal course to your original one. In many ships you will find you are now on or close to your original track.

Picking up by boat. It is usual to pick up the man by lowering a boat. Traditionally the call 'Away lifeboat's crew!' in place of the usual 'Away seaboat's crew!' means that the boat is for saving life, and any officer or man nearby, whatever his rank or duty, should leap to the boat to man her. In fact, at sea the seaboat's crew is detailed and ready and should be in the boat before anybody else. However, it may well be preferable to use the traditional call in order to alert everybody, including the seaboat's crew, to the urgency of the situation.

The lowering and hoisting of seaboats, and hints to coxswains on how to pick up a man, are covered in Volume I.

Picking up by swimmer. If the weather or the tactical situation precludes lowering a boat it may be best, having placed the ship alongside the man overboard, and to windward of him, to use a swimmer to help get him inboard. The swimmer should wear flippers. If the weather is cold he should wear a shallow-water diving suit and an inflatable lifejacket. A lifeline should be secured to the becket on the lifejacket, at the back of his neck. Operations should be carried out from a scramble net over the ship's side. It is good policy always to have a second swimmer dressed and ready to help if needed.

Running into fog

When visibility closes down to within about a mile the precautions to be taken depend on whether the ship is alone or in company and whether it is peace or war. As soon as you find the visibility is closing down, or if you sight a fog bank ahead, inform the Captain. The normal action to be taken in peace is as follows:

When alone:

1. Reduce to a moderate speed.
2. Operate radar, and have a surface plot manned, if these are not already done.
3. Station extra lookouts (see remarks earlier in this chapter).
4. If in soundings, start sounding.
5. If in the vicinity of land, have an anchor prepared for letting go.
6. Review the ABCD state of readiness and watertight condition (see remarks earlier in this chapter) and order changes if necessary.
7. Order silence on deck.
8. Start the prescribed fog signal and see that the man who works it can time it accurately.
9. Warn the engineering department and order additional boilers or engines to be connected, if necessary.
10. If in any doubt about the ship's position, alter course to a safe course, parallel to or away from the coast (or danger), or stop the ship.

The remarks about passages in fog and thick weather given in B.R.45(1), *Admiralty Manual of Navigation*, Vol. I, should be carefully studied by every Officer of the Watch.

When in column:

1. Station a lookout aft if there is not one already.
2. Switch on the fog light.
3. Stream a fog-buoy or target to the prescribed distance as an aid to the ship astern to keep station (if ordered by the Force Commander).

The Force Commander may be expected also to signal orders about speed, the sounding of fog signals and the showing of navigation lights. Tactical instructions in force in the Fleet contain further orders about the conduct of ships in company in fog, and how these should be applied in war.

It is particularly important to know exactly what is laid down in the International Regulations for Preventing Collisions at Sea regarding the conduct of ships in fog.

Running into ice

The chief danger of drifting ice is that it is frequently accompanied by fog, and when steaming in regions where ice may be encountered a good watch should be kept for signs of the proximity of ice.

Signs of there being ice in the vicinity are as follows:

Ice blink, which is a reflection of light from large masses of ice. On a clear day or night, and particularly on a moonlit night, the sky along the horizon in the direction of the ice is markedly paler or lighter in colour than along the remainder of the horizon.

Absence of sea or swell in a fresh breeze which, in the absence of land, indicates that ice is on the weather side.

Calf ice (small floes), which is a reliable sign of the close proximity of icebergs. When encountered in a curved line, the parent berg will be on the concave side of the line.

Herds of seals or flocks of razorbills far from land.

Loud noises akin to gunfire or heavy breakers, caused by large masses of ice breaking off icebergs which are disintegrating.

Echoes from the siren, which may be received from nearby and high icebergs.

When steaming near icebergs, it should be remembered that about seven-tenths or more of their mass is below water and may project horizontally near the surface for a considerable distance from their sides. If, in low visibility, an iceberg is sighted a short distance ahead the best avoiding action is to go full speed astern, because if you turn to avoid it the submerged and projecting ledges of the berg may rip your bottom out.

RECORDS

Navigating Officer's or Officer of the Watch's Notebook

This is a small unruled notebook (Form S.548A) provided on the bridge for recording navigational observations, other than astronomical ones. When land is in sight or detected—and in the absence of the Navigating Officer—the Officer of the Watch must enter all his bearings, etc. in this notebook at the time of observation. If space does not permit the recording of all courses and speeds in the Ship's Log, a complete record is to be kept in the Notebook.

Ship's Log

Instructions for the writing up of the ship's log are contained inside the front cover. At the end of his watch the Officer of the Watch completes his entries and initials the book before leaving the bridge. He should supervise and train his subordinates to take readings accurately and to make accurate estimates of the state of the sea and weather.

Wheel and Engine Orders Record Book

When entering or leaving harbour, when manœuvring, or on any other occasion that seems to require it, the Officer of the Watch must see that a record of all wheel and engine orders is made in this book.

Fishing Vessel Log

Full details of any encounters with fishing vessels in Home Waters are entered in this book. The details are required in order to refute or substantiate claims for loss or damage of gear subsequently made by the fishing vessels concerned.

CONCLUSION

It may be thought that too cautious an attitude has been inculcated in this chapter. In fact the seaman's first need is an awareness of the dangers of the sea. A perpetual wariness and alertness forms the basis on which he can build wisdom and confidence, so that when suddenly faced with danger he remains calm and acts swiftly, because he is ready.

CHAPTER 12

Propulsion and Steering of Ships

The way in which a vessel behaves when being manœuvred depends upon a number of variable factors. These include her means of propulsion, her steering, the shape of her hull, the disposition of her superstructures, her loading and trim, the weather, the depth and extent of the water surrounding her, and the presence of current or tidal stream. It is obvious that the handling of one ship may be very different from that of another. However, certain fundamental principles apply to all shiphandling situations. Experience naturally helps to increase the skill and competence of the shiphandler, but any officer who undertands the principles of shiphandling, who has a good knowledge of seamanship and who prepares carefully for each manœuvre, should be able to handle his ship successfully. In this and subsequent chapters the principles of shiphandling and how they should be applied in different circumstances are described.

PROPELLERS

When studying the handling qualities of any particular class of ship, the first considerations are the number and size of the propellers and the horsepower and type of the propelling machinery. Handling a single-screw ship fitted with reciprocating engines is very different, for example, from handling a quadruple-screw ship with turbine engines.

Single screws

In a single-screw ship the propeller is almost invariably right-handed; that is, when the ship is driven ahead the propeller revolves in a clockwise direction when viewed from astern. In order to go astern the rotation of the propeller is reversed. Some frigates and tugs and the majority of fleet tankers, maintenance ships and servicing craft are single-screw ships. A large proportion of merchant ships have single screws. It is more efficient to drive a submarine under water by a single screw, and for this reason high-speed or nuclear-powered submarines are usually fitted with only one screw.

Twin screws

Most major warships, including submarines, have twin screws. In all cases the screws, except where they have controllable pitch, are out-turning—that is, they are right-handed on the starboard side and left-handed on the port side.

Quadruple screws

Some large warships have out-turning quadruple screws, two on each side. It is customary to work both the propellers on each side ahead or astern together, but the fitting of a separate telegraph for each shaft permits each screw to be operated individually. It is possible in this case also to work the two inner

screws together and the outer screws separately, thus producing the effect of having three screws. In some quadruple-screw merchant ships the outer propellers of each pair are used when manœuvring and the two inner propellers cannot be driven astern.

Triple screws

One class of aircraft carriers in the Royal Navy was fitted with triple screws, one each side and one on the centre line immediately before the rudder. In 1963 there was still one survivor of this class—H.M.S. *Victorious*, with outer propellers out-turning and the centre propeller left-handed.

Some fast coastal craft are fitted with triple screws, but some also have two or four; usually all the propellers in the craft revolve in the same direction, so as to facilitate engine installation.

Controllable-pitch propellers

A small number of frigates and inshore minesweepers and some tugs have twin controllable-pitch propellers. In these frigates the propellers are in-turning, but the shafts revolve always in the same direction, the astern power being obtained by reversing the pitch of the screws.

Design of propellers

Three-bladed propellers are most common in H.M. ships, though four- and five-bladed propellers are occasionally fitted. Both the diameter and the pitch of the propellers react on the shiphandling qualities of the ship. In general, ships with steam reciprocating engines have large and comparatively slow-turning propellers, whereas in most turbine-engined ships (unless double reduction gearing is fitted) faster-turning, smaller propellers are necessary. Broadly speaking, the larger the propeller the smaller is the loss of power through slip and the sternward velocity of the slipstream or race, and the greater is the efficiency.

Diesel engines are economical and most efficient if they can be kept running steadily at a reasonably high speed. Controllable-pitch propellers are fitted in conjunction with diesels to enable this to be done.

PROPULSION MACHINERY

Type of machinery

Steam turbine machinery with single or double reduction gearing is fitted in the majority of H.M. ships. In the remainder a variety of propulsion machinery is found—diesels, gas turbines, steam reciprocating engines, or steam turbines with gas turbines in addition.

Acceleration and deceleration

The acceleration or deceleration capability of the ship depends largely on two factors—the horsepower available and the momentum of the ship. Momentum is the product of weight and speed. To compare the ahead and astern powers of different classes of ship one can consider first the ***full-ahead momentum*** of each class. For example, a ship of 2,000 tons with a maximum speed of 30 knots

would have a full-ahead momentum of 60,000 knot-tons. Then one can compare the ratio of the ahead (or astern) horsepower available to the full-ahead momentum in different classes. In fig. 12–1 examples of four classes are shown—a cruiser, a destroyer, a minesweeper and a depot ship. On the right are horses representing ahead power. The size of the shaded area on which each horse is drawn represents the ahead horsepower available *per unit of full-ahead momentum.* On the left are 'captains' whose areas represent astern power, i.e. the available astern horsepower in each class per unit of full-ahead momentum.

The depot ship is of comparable size, speed and horsepower to many types of merchant ships, and it will be seen from the figure that the man-of-war types—cruiser, destroyer and minesweeper—are relatively much superior to her in ahead and astern power. The destroyer, or the high-speed frigate, has particularly good powers of acceleration and of stopping and this gives her great advantages in manœuvring if she is wisely handled and the extra power is not misused. The minesweeper shown has reciprocating machinery, whereas the three other ships have steam turbines. Note the excellent astern power conferred by reciprocating engines. This is so because the same engines are used both ahead and astern. In a steam-turbine ship the main turbines can drive the shafts ahead only, and additional smaller turbines are fitted to drive the shafts astern. Factors affecting the acceleration and deceleration of ships are discussed in detail later in this chapter.

Astern power

In naval ships fitted with steam turbines the astern power is usually about one-third of the ahead power. But because of the inefficiency of the astern turbines the steam consumption, or boiler power, at full power astern is similar to that required for full power ahead. In other words, slow astern will require three times the boiler power required for slow ahead for similar speeds. With reciprocating steam engines the astern power is nearly as high as the ahead, and maximum power astern can be developed almost as quickly as for ahead.

A series of propeller trials in a destroyer having steam turbines of 40,000 h.p. produced some interesting data. It was shown that with a well-trained engine-room staff the ship could achieve almost full astern revolutions in two minutes. In going direct from full ahead to full astern the ship was stopped in one and a quarter minutes and was going at full speed astern in two and a half minutes. However, such figures represent the optimum, and it is extremely unlikely that they could be obtained in a normal commission.

One limiting factor is the temperature of the turbines. The rate at which it is possible to work up power without damage to the machinery depends on whether the machinery has been thoroughly warmed through. It is far more dangerous to work up fast while leaving harbour than when the machinery has been steaming for some time.

Emergency power

'Full astern' is an emergency order and should only be used if the ship is in danger. If a sudden burst of power either ahead or astern is needed while manœuvring the revolutions should be increased by a sizable amount with the telegraphs still at *half* speed. Even if these revolutions are rung off before the

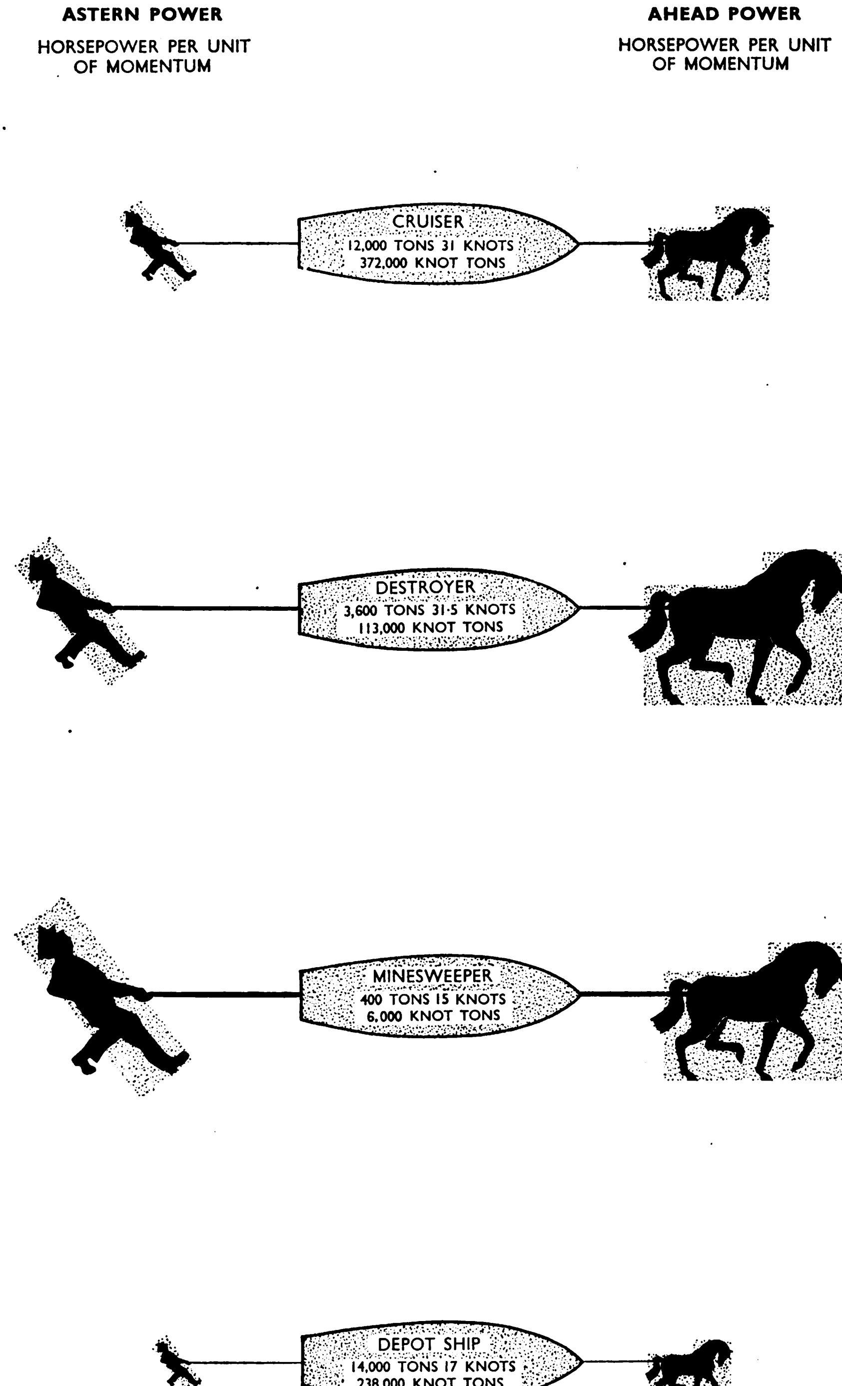


FIG. 12–1. Comparison of ahead and astern power in different classes of ship

shafts attain them this procedure will indicate to the engine-room staff that prompt rather than emergency action is required, and damage to the boilers or machinery can thus be avoided.

RUDDERS

Prime function of the rudder

Imagine a model ship floating in a tank with a vertical rod projecting upwards from her pivoting point (*P* in fig. 12–2). When a ship is moving ahead, *P* can be assumed to be about one-third of the ship's length from the bows. Suppose the ship to be propelled forward along a steady course. Now consider what happens when a twisting moment is applied suddenly to the vertical rod. The ship *yaws* or turns away from her original course by a certain angle. Owing to the ship's shape, the pressure of water on her hull now acts predominantly *abaft* the

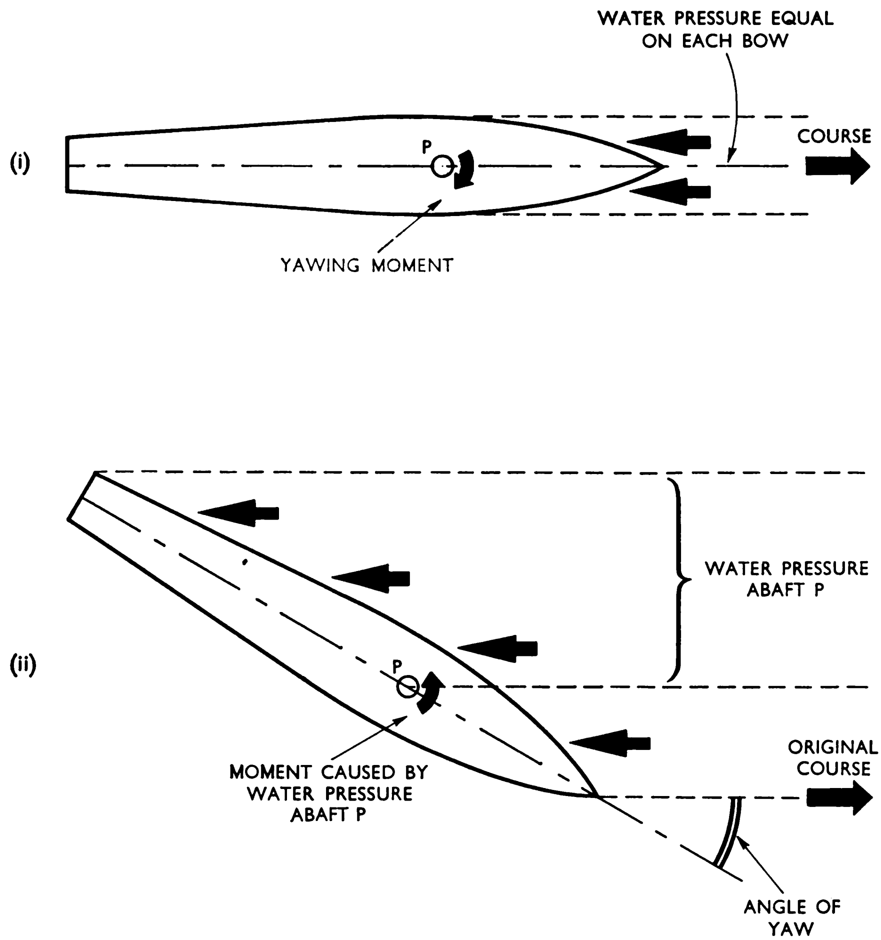


FIG. 12–2. Effect of water pressure on hull of ship moving forwards (i) before a yaw, (ii) immediately after a yaw

pivoting point and thus sets up a moment tending to swing the ship's bow back to the original course (fig. 12–2 (ii)). If a turn is to be maintained, this moment must be counteracted and the best way of doing this is to apply a force at the end of the ship where the lever will be a maximum. This is normally done by means of a rudder at the after end.

The prime functions of the rudder are therefore first to produce the moment to start the ship turning, and secondly to keep her turning (if desired) by resisting the tendency of the water pressure to push her back on to her original course.

Deadwood

The rudder can be used, however, for another important function. Most hull forms need some flat vertical surfaces aft to maintain course stability and to ensure easy course-keeping. The action of such vertical area, or *deadwood*, is to apply a sideways force, and hence a correcting moment, as soon as the ship starts to yaw. The deadwood thus hinders turning, and must be reduced in order to get good turning qualities. Therefore it appears at first that good course-keeping is incompatible with good turning. However, by judicious balance of hull shape and rudder area it can be arranged that the rudder itself provides sufficient deadwood effect when held amidships (or near it) to obtain good course-keeping stability, and then, when the rudder is put over, the course stability is much reduced and the vessel turns easily. This effect has been achieved successfully in recent designs of destroyers and frigates for the Royal Navy.

Types of rudder

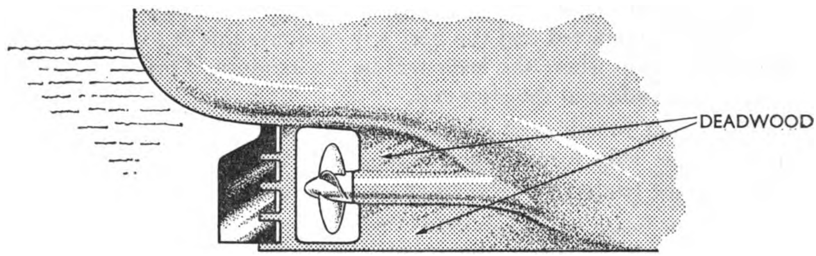
The conventional hinged unbalanced rudder (fig. 12–3 (i)) is found in many merchant vessels, but warships are generally fitted with a balanced rudder (fig. 12–3 (ii)).

Hinged rudders

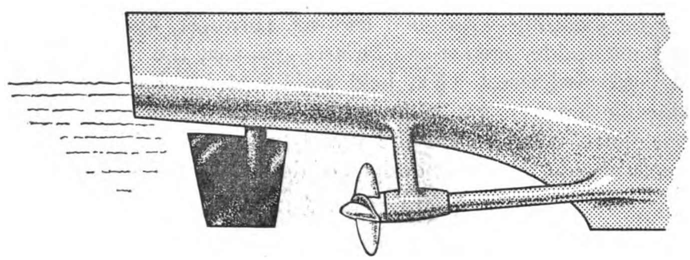
The unbalanced rudder is hung on pintles on a vertical stern post and is therefore hinged at its forward end. This type of rudder requires more power to operate it than a balanced rudder and is generally less effective. It is of interest to note, however, that it is more effective than a balanced rudder at the start of a turn. This is because water pressure is increased against the deadwood on the same side to which the rudder is moved. This pressure helps to start the ship turning (fig. 12–4), but as soon as she does so, the water pressure on the other side of the deadwood, caused by the ship swinging, cancels this effect, and the rate of turning is reduced.

Balanced rudders

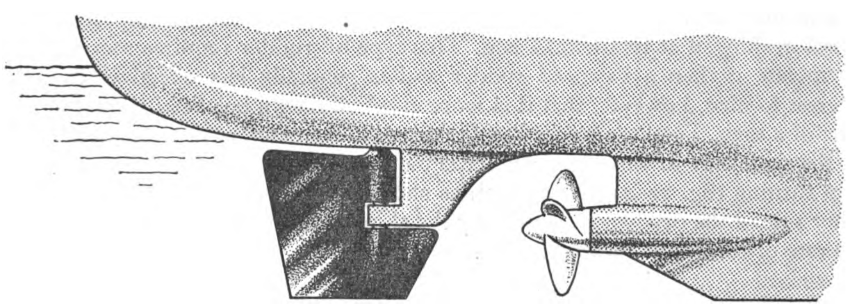
The balanced rudder as fitted in warships is usually supported entirely by the rudderhead within the hull. The ship's hull is cut away to a certain extent in the area before the rudder to improve her turning qualities, while the rudder itself acts partially as deadwood. About 25 to 30 per cent of the area of a balanced rudder lies before its axis. This has the effect of reducing the power required to turn the rudder with the ship moving ahead. Some ships have a balanced rudder



(i) Hinged unbalanced rudder



(ii) Balanced rudder



(iii) Balanced rudder, partially supported outboard

FIG. 12–3. Types of rudder

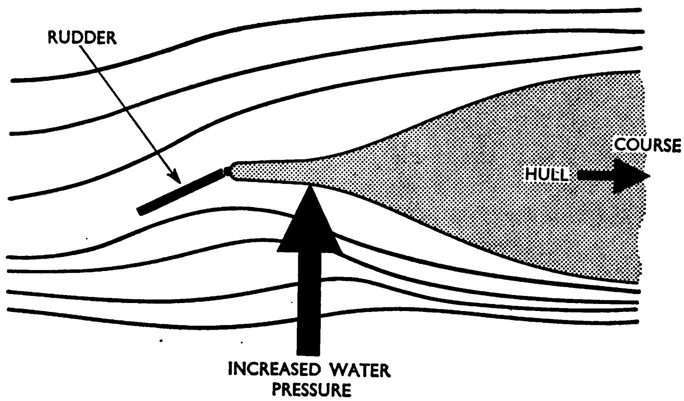


FIG. 12–4. Immediate effect of putting over a hinged unbalanced rudder

that is partially supported outside the hull by an extension to the keel carrying a pintle (fig. 12–3 (iii)). This design suffers from the disadvantage that the flow of water on to the rudder is disturbed.

Rudder angle

Long experience has indicated that a maximum rudder angle of 35° is satisfactory. An angle of 45° will give a tighter turn, but will reduce speed more. However, the additional turning capability is an over-riding advantage in some classes of ship and 45° rudder angle has been incorporated in some recent designs of warship. At high speeds, however, a phenomenon called *burbling* is liable to occur. Burbling is akin to cavitation and occurs when the suction abaft the rudder reaches a value equal to the vapour pressure of the water so that bubbles of water vapour are formed. If burbling occurs the force from the rudder drops suddenly and the turn widens.

Modern rudder construction

The modern rudder has a thick section with a flat bottom and nearly parallel sides. This form has been found to delay the onset of burbling as compared with former designs, which were more rounded and tapered.

ARRANGEMENT OF PROPELLERS AND RUDDERS

Propeller slipstream

The positioning of the rudders in relation to the propeller slipstream is of primary importance. A rudder directly in the wake of a propeller is affected not only by the flow of water created by the ship's forward speed but also by the slipstream, which is travelling appreciably faster relative to the rudder than the other water in the wake. This slipstream, or propeller race, is particularly advantageous when manœuvring with little headway.

Single rudder

In the single-screw ship there is usually one rudder placed immediately abaft the propeller. This rudder is well placed to catch the greatest effect from the propeller race, and when going ahead from rest the rudder will have an immediate effect even before any headway is gathered.

In a twin-screw ship the single rudder is placed between the slip-streams from the propellers, as shown in fig. 12–5, and therefore it cannot enter the slip-stream until it has been given a large angle. This is a disadvantage both when there is little headway on the ship and also at the beginning of a turn.

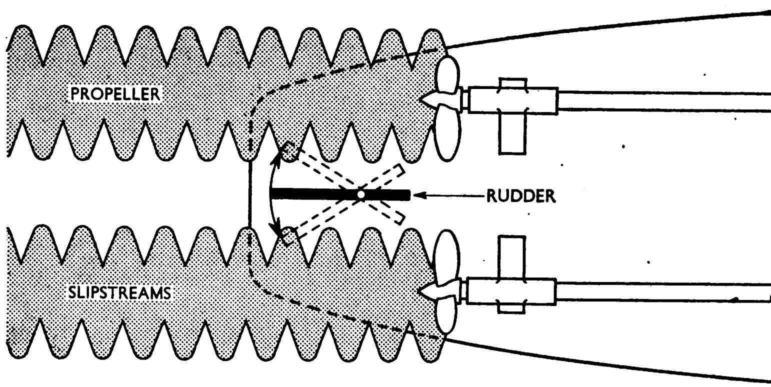


FIG. 12–5. Position of single rudder in relation to twin propellers, seen from below

In a triple-screw ship the centre propeller is usually placed just ahead of the rudder so that it will throw its race directly on to the rudder and give good turning capability at slow ahead speeds.

Twin rudders

To improve the turning qualities of the twin-screw ship twin rudders can be placed so that each is in the slipstream of a propeller (fig. 12–6). In the quadruple-

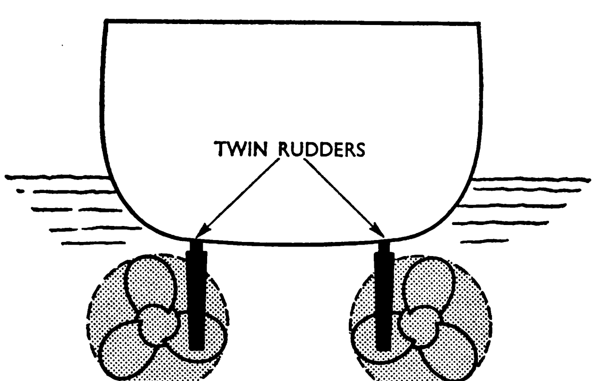


FIG. 12–6. Position of twin rudders in relation to twin propellers, seen from aft

screw ship the rudders can be fitted in the wake of the two inner (after) propellers. Such an arrangement is used in several classes of ship in the Royal Navy and gives better all-round manœuvring qualities than those obtainable with a single rudder between the propellers. The advantage of twin rudders is marked at slow speeds and smaller rudder angles.

Effects of hull form on rudder efficiency

The effect of a rudder of given design is dependent on the speed and turbulence of the water meeting it, so that in addition to the relative position of the propellers the form of the hull aft modifies the turning powers of a ship moving ahead.

In ships with bluff or rounded sterns the wake effect is large and the speed of the water passing the rudder may be as much as 35 per cent less than that of the ship. The eddying may cause part of the rudder to be in disturbed or dead water. This effect will be accentuated if the propeller is stopped and thus dragged through the water immediately ahead of the rudder. Conversely, in a ship with a fine run the reduced wake effect will result in greater rudder efficiency.

PROPELLER ACTION

For various reasons a ship's propeller does not usually produce a force acting exactly in the line of the shaft, and the net resultant force exerted by the propeller is usually at an angle to that line. It is convenient, however, to consider the net force of the propeller as consisting of two components, acting as follows:

1. either directly ahead or astern (in the line of the propeller shaft);
2. sideways, that is, either to the right or the left when viewed from astern.

Sideways force

The sideways force of the propeller is caused by the shape of the hull and rudder and the relation of the propeller to them. The causes of the force are not fully understood, but the description of propeller action that follows is based on practical experience, and should enable the shiphandler to assess the sideways force and its effects in his particular ship. The wake caused by the hull shape is complex and can be shown to have several components. For example, the *frictional wake* consists of water close to the hull being dragged along by skin friction. The flow of water past the propeller is not of uniform speed over the whole area traced out by the blades, so that a sideways component, caused by the wake, of the propeller force is almost always present. A detailed analysis of the causes of the sideways force exerted by a propeller would not be particularly helpful to the shiphandler. However, he will find that in almost all cases the propeller behaves as though it gave rise to three effects, which, when considered together, indicate which way the sideways force will act. These three effects can be called: *paddlewheel* effect, *pressure-and-suction* effect, and *lateral-wash* effect.

Paddlewheel effect

In both single-screw and multiple-screw ships the propellers behave as if they met with greater resistance at the bottom of their travel. Even if the whole propeller is immersed the effect is similar to that caused in a merchant ship in ballast when the blades actually come out of the water at the top of their travel.

The right-handed propeller when viewed from astern is rotating clockwise to drive the ship ahead, and this sideways *paddlewheel* effect pulls the stern to starboard and thus tends to turn the ship to port (fig. 12–7). Conversely, the

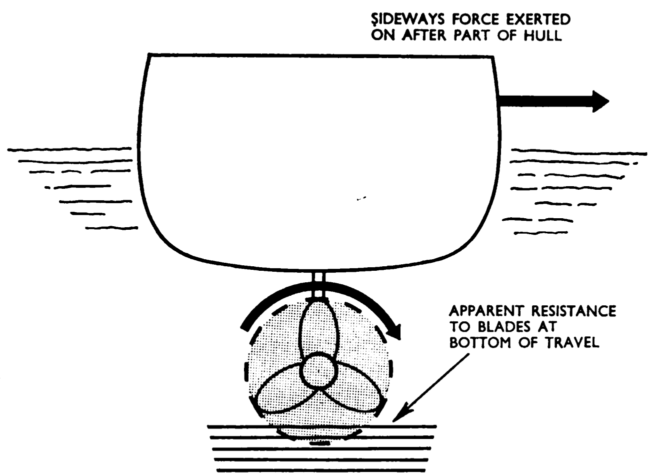


FIG. 12–7. Paddlewheel effect (viewed from astern) from a single propeller rotating clockwise, causing the vessel to turn to port

right-handed screw when going astern kicks the stern to port and turns the whole ship to starboard. A full scientific explanation of this phenomenon is not at present available, although current experiments may throw more light on it.

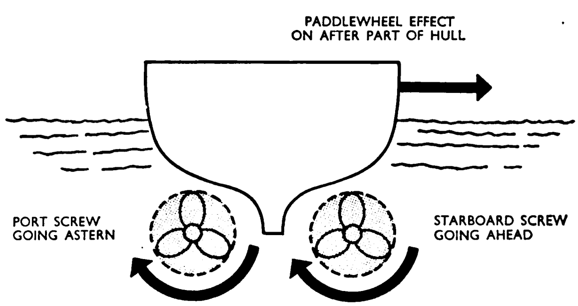


FIG. 12–8. Paddlewheel effect (viewed from astern) in a ship with twin out-turning screws turning at rest to port

The effect, however, is *not* caused (as was previously supposed) by differences in the pressure or density of the water at different levels.

Suppose it is desired to turn at rest to port in a twin-screw ship with out-turning screws. The shiphandler puts the starboard screw ahead and the port astern, and it can be seen that the paddlewheel effect from each screw helps to turn the ship in the required direction (fig. 12–8); and these effects are equally helpful when turning at rest to starboard.

Pressure-and-suction effect

When going ahead the propeller is drawing water away from the hull, and when going astern it is throwing water on to the hull. In a single-screw ship this is unlikely to cause much sideways effect, but consider again a twin-screw ship (with out-turning propellers) turning at rest to port with the starboard screw going ahead and the port astern (fig. 12–9). The starboard screw is drawing water away from the starboard quarter, so causing a loss of water pressure against the hull there; while the port screw is throwing water against the port quarter and increasing the pressure there. The combined effect is to produce a

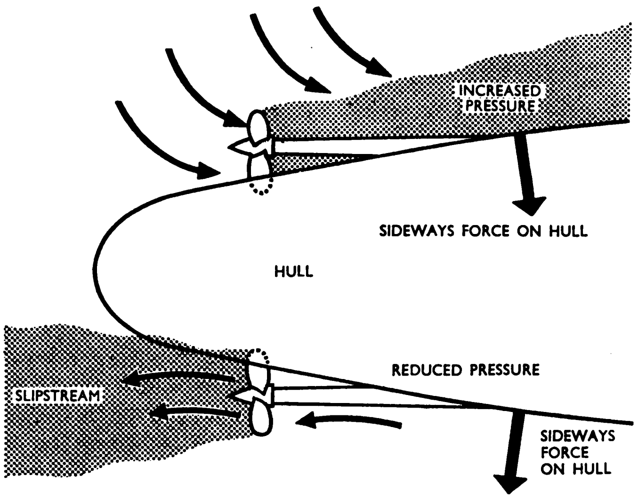


FIG. 12–9. Pressure-and-suction effects in a twin-screw ship with out-turning screws turning at rest to port, viewed from above

sideways force pushing the stern to starboard, so helping the ship to turn to port. Similarly this effect assists a twin-screw ship turning at rest to starboard. The extent to which this effect is felt depends on the shape of the hull aft and the position of the propellers in relation to it.

Lateral-wash effect

If the ship is moving ahead or astern the rotating propellers throw the water directly astern or ahead. When the ship is turning at rest, however, the supply of water to each propeller is restricted and slip develops, so that some of the water, instead of being pushed forward or aft, is thrown out laterally. Consider again the twin-screw ship with out-turning screws turning at rest to port. It can be seen from fig. 12–10 that the blades of the port screw during the upper part of their rotation are throwing water out laterally against the hull and so helping to turn the ship to port, while the blades of the starboard screw are pushing water away from the hull and also assisting the turn. Similarly this lateral-wash effect helps to turn the twin-screw ship at rest to starboard. Again, it must be realised that the extent to which this effect is felt depends on the position of the propellers in relation to the hull.

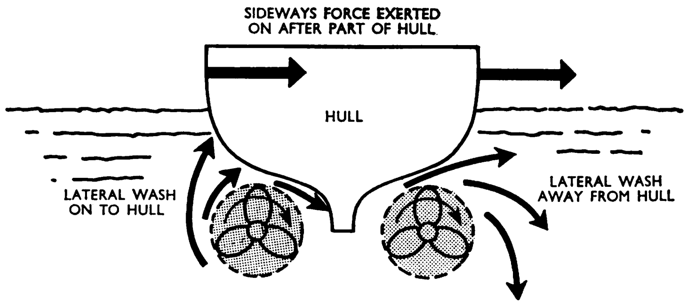


FIG. 12–10. Lateral-wash effects (viewed from astern) in a twin-screw ship with out-turning screws turning at rest to port

Thrust

We find therefore that each of the three components of the sideways force of the propellers in a twin-screw ship with out-turning propellers helps to turn her at rest in the direction intended. If he wishes to turn at rest to port the ship-handler puts the starboard engine ahead and the port astern, because common sense tells him that the thrust in the fore-and-aft line by the propeller shafts on to the thrust blocks will pull the ship in the required direction. However, the distance between the shafts is small in relation to the length of the ship and hence the couple exerted may not be very great (fig. 12–11). Not much scientific data are available as to which has the greater effect—the fore-and-aft thrust or the sideways forces. It is generally assumed that the sideways forces (paddlewheel, pressure-and-suction effects and lateral wash) are as strong as, or possibly stronger than, the thrust.

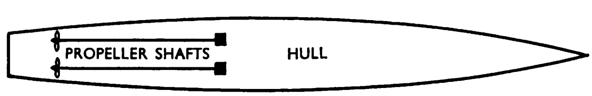


FIG. 12–11. The moments exerted by the propeller shafts on the thrust blocks, viewed in relation to the length of the ship

A little reflection will reveal that if a ship has *in-turning* screws, paddlewheel effect and lateral wash will act in opposition to pressure-and-suction effect and to the fore-and-aft thrust when she is turning at rest. The first two effects are opposing the turn and, if they were stronger than the latter two effects, the shiphandler would have to reverse the engines: that is, he would have to put the *starboard* engine *astern* and the *port ahead*, if he wished to turn to *port*. However, such a situation, even in a ship with in-turning screws, would be most exceptional. But some merchant ships with in-turning screws have been found to be notoriously sluggish in turning at rest. There are a few diesel-engined frigates in service with in-turning propellers, but since these have controllable pitch, the screws are not reversed when going astern. These ships turn well at rest if the two shafts are handled in the conventional manner.

The shiphandler will gain, however, a better understanding of how his ship will manœuvre if he keeps in mind the existence of the sideways propeller

forces as well as the fore-and-aft thrusts. It will probably be helpful for him to have a good look at the after part of the hull and of the relative positions of propellers and rudders, when the ship is in dock or by studying her drawings. The ship's manœuvrability depends, however, upon many other external factors, which have already been mentioned and which will be discussed later in this chapter. Shallow water in particular may modify greatly the effects already described.

Single-screw ship

If a ship with a single right-handed screw proceeds ahead from rest the paddle-wheel effect carries her stern to starboard, and hence tends to turn the ship to port, initially. As headway is gained this effect is progressively reduced. Thus it is usually necessary at first to apply starboard wheel to keep the ship on a steady course, but the amount of wheel can be gradually reduced as the ship gathers speed. When the screw is put astern the effect is to swing the stern to port and this effect is noticeable even after sternway has been gained. Often this swing is so strong when going astern that it cannot be counteracted even by full opposite rudder. The question of how best to turn a single-screw ship at rest is discussed in Chapter 13.

TURNING

Forces acting on a ship turning

When anything moves in a circular or curved path there is an acceleration towards the centre of the path. This acceleration is caused by a force called *centripetal* force. In a ship the centripetal force is the resultant of all the lateral forces acting on the hull and rudder. The centripetal force on the hull alone acts through the pressure of sea water on one side of the hull, and it can be assumed that it acts through a point called the centre of pressure (*S* in fig. 12–12). When the rudder is first put over, and before the ship has begun to turn, the ship will probably heel inwards, because the rudder force acts below the centre of gravity *G* (fig. 12–13 (i)). In addition there is a tendency for the ship to be

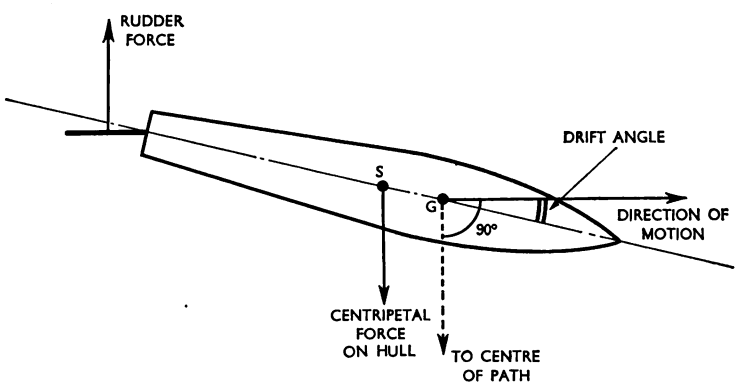


FIG 12–12. Forces acting on a ship while turning. *S* is the centre of pressure

pushed bodily outwards from her original line of advance. As the ship begins to turn, she heels outwards because the centripetal force on the hull (which is greater than the rudder force) normally acts at a point below her centre of gravity (fig. 12–13 (ii)). The ship now travels along a path of gradually increasing curvature until, after turning through about 90°, the path becomes approximately circular.

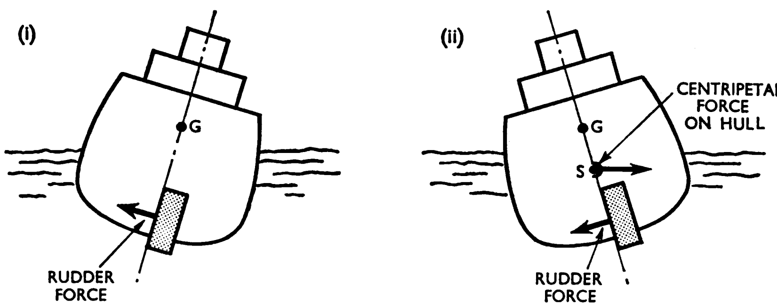


FIG. 12–13. Forces acting on a ship (i) immediately rudder is put over, (ii) when ship begins to turn

Drift angle

Consider the paths described by various parts of a ship turning under rudder when steaming ahead (fig. 12–14). Each point in the ship must follow a path approximately concentric with that described by the centre of gravity. The angle made by the tangent to the curved path of any point with the fore-and-aft line is known as the *drift angle* at that point at any given instant.

The drift angle has its highest value at the stern and diminishes gradually as you go forward along the ship until a point is reached, usually nearer the bow than the stern, where it is zero. From that point, as you move forward, drift angle has an increasingly opposite value. When drift angle is quoted this normally means that at the centre of gravity.

The value of drift angle is dependent on a number of factors such as the ship's underwater form and design of rudder, her displacement and speed, and the direction and force of the wind; but in any particular ship it is principally dependent on the angle of rudder in use. As angular momentum increases during the early stages of a turn, so drift angle rapidly increases. In a turn using steady rudder angle the drift angle at the centre of gravity eventually settles down to a figure in the region of 10° after the ship has turned through about 90°.

Pivoting point

The point where drift angle is zero is called the *pivoting point* of the ship (*P* in fig. 12–14). This point is moving directly along the fore-and-aft line at any given instant, and to an observer there the bow will appear to be swinging towards the centre of curvature at the same rate as the stern is swinging away from it.

The position of the pivoting point moves, being influenced by the same factors that determine the value of the drift angle. It is dependent more on the ship's speed than on the angle of rudder in use. In a large ship during a turn it may

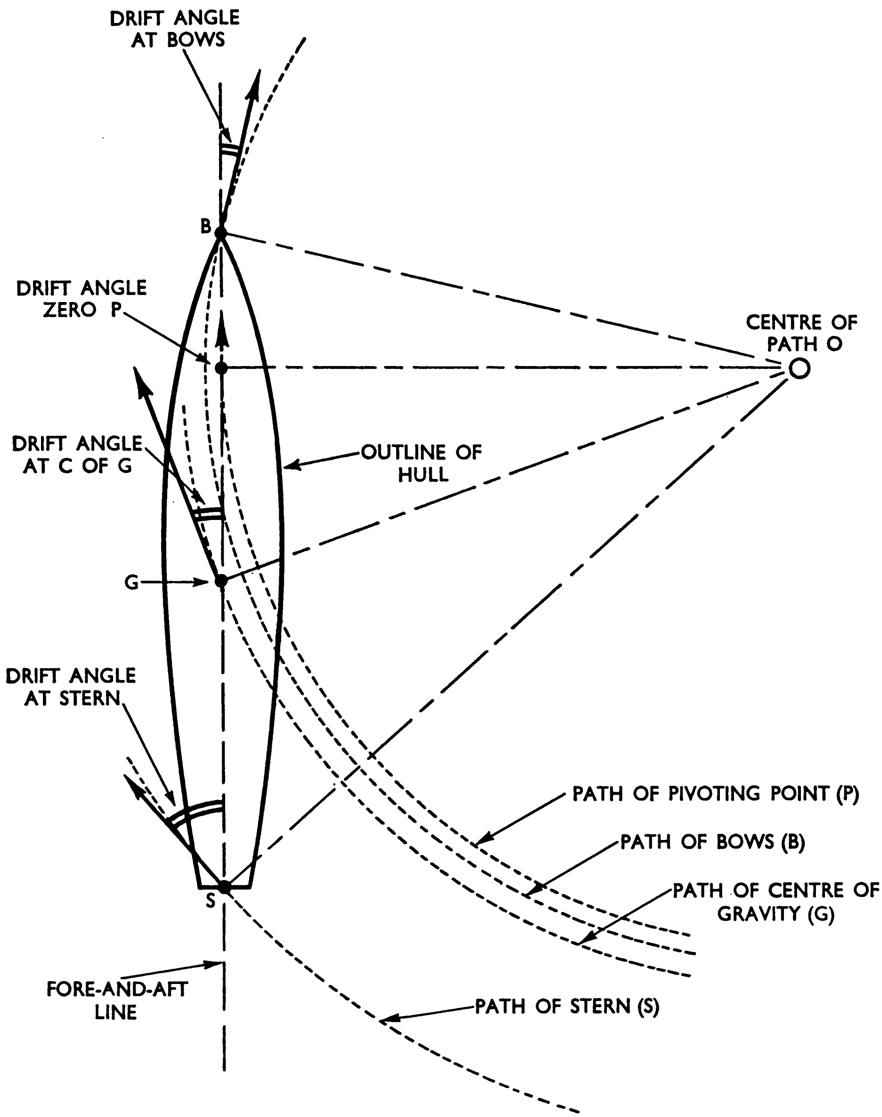


FIG. 12–14. Paths described by various parts of a ship turning under rudder when steaming ahead. (The radius of the turning circle shown is much smaller than normal.)

oscillate between the bows and the centre of gravity. For practical purposes an average position must be established.

It can be taken that in large ships of orthodox hull shape, such as aircraft carriers and cruisers, the average position of the pivoting point when going ahead is about one-third of the ship's length from the bows. In destroyers or frigates it may well be further forward, while in motor torpedo boats or similar fast light craft it may be ahead of the boat when she is turning at speed. When

K*

a ship has sternway the pivoting point usually moves to a position nearer the stern than the bows.

It can be seen from fig. 12–14 that the radius of curvature of the ship's path is greater at the stern than at the pivoting point, the more so as drift angle increases. This fact must be taken into account when plotting in advance the intended track of the ship in restricted waters, e.g. when it is intended to turn into harbour between two breakwaters. Clearly one should not execute such a manœuvre under a large angle of wheel, if avoidable.

Turning circle

The path of a ship's compass platform as she turns through 360° at a certain speed (i.e. at a steady value of revolutions-per-minute of the propellers) and with a certain rudder angle is called her *turning circle*. From what has been said it is evident that the path of her stem will be very nearly the same as this turning circle but the path of her stern will be well outside it. However, since it is convenient to plot turning circles for different speeds and angles of wheel from the compass platform, this definition is used. Thus the turning circles given in the ship's data may not coincide with the turning circles traced out by her pivoting point, although in most ships they will not be dissimilar, because the compass platform is usually not far from the pivoting point when moving ahead.

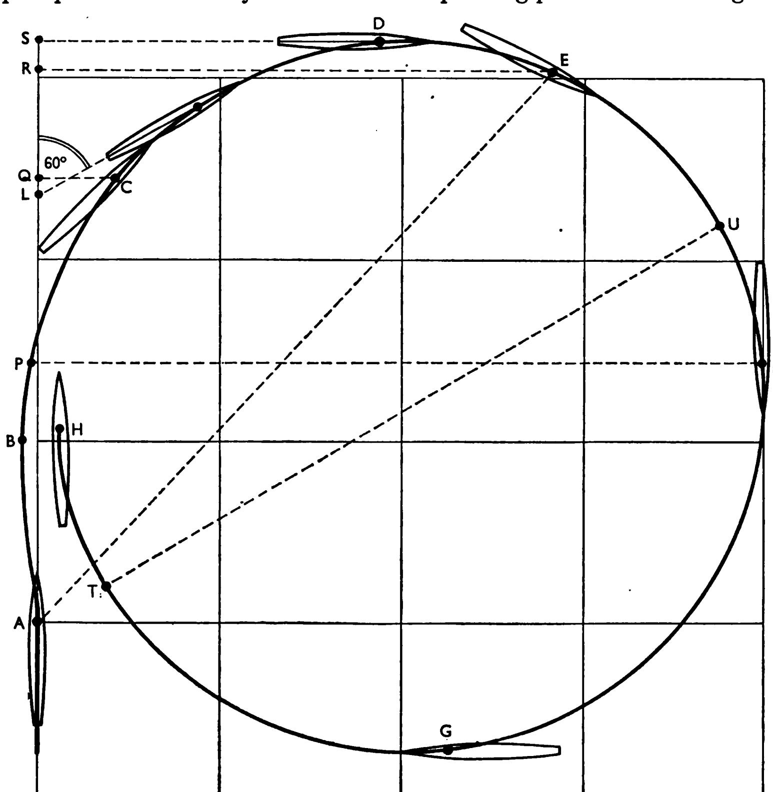


FIG. 12–15. A typical ship's turning circle

A typical turning circle is shown in fig. 12–15. It can be seen that after turning through 360° the compass platform is usually slightly ahead of, and slightly inside of, the point at which the wheel was originally put over (*H* in fig. 12–15).

In fig. 12–15 *A* is the position of the compass platform at the moment of starting to put the rudder over. *B* is the position at which the ship begins to turn. *C*, *D*, *E*, *F*, *G*, *H*, are the positions where the ship has turned through 45°, 90°, 120°, 180°, 270°, 360° respectively. The distance *AB* is dependent on the speed of the ship, the rate at which the rudder is applied and various other influences, such as the wind. On completion of a 360° turn, as already stated, most ships are inside their original track, as at *H*, but some are outside it.

The following definitions are used in connection with turning circles:

The ***advance*** of a ship for a given alteration of course is the distance that her compass platform moves in the direction of her original line of advance, measured from the point where the rudder is put over. *AQ* is the advance for a turn of 45°; *AR* the advance for 120°.

The ***transfer*** of a ship for a given alteration of course is the distance that her compass platform moves at right angles to her original line of advance, measured from the point where the rudder is put over. *SD* is the transfer for a turn of 90°.

The ***tactical diameter*** is the amount that the compass platform has moved at right angles to the ship's original line of advance when she has turned through 180°. In other words, it is the transfer for an alteration of course of 180°, i.e. *PF* in fig. 12–15.

The ***final diameter*** is the diameter of the turning circle when the ship's path has finally become approximately circular, i.e. *TU* in fig. 12–15.

The ***distance to new course*** is the distance, measured along the original line of advance, from the position of the compass platform when the rudder is put over to the point of intersection between the old and new courses. *AL* is the distance to new course for a turn of 60°. For turns of over 135° the distance to new course becomes too large to use as an accurate means of plotting the track.

The ***intermediate course and distance*** gives the length and direction of the line joining the position of the compass platform when the wheel is put over and the position when the ship has turned through any particular angle. In fig. 12–15, *AE* is the intermediate distance for a turn of 120°. The intermediate course for this turn is the angle *SAE*.

Effect of hull form on turning circle

A ship of fine underwater form will turn in a larger circle than a ship of similar length and draught but of fuller form. Modern warships are generally of great length in proportion to beam and thus tend to have large turning circles, but great improvements in turning capability have been achieved in recent classes through fitting rudders of improved design, and through fitting twin rather than single rudders. The shape of the underwater part of the hull aft, particularly the ***cut-up*** area, as shown in fig. 12–16, has a most important effect on the size of the turning circle. Certain external effects, such as that of wind, on the size of the turning circle are discussed later in this chapter.

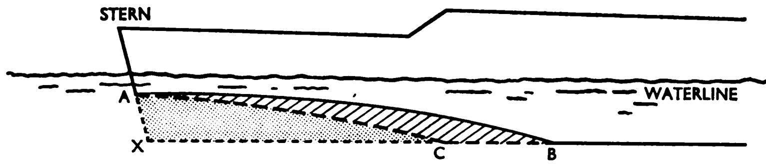


FIG. 12–16. Effect of cut-up area on turning qualities. The ship with the larger cut-up area *ABX* will have a smaller turning circle than the one with the smaller cut-up area *ACX*

Effect of single screw on turning circle

Because of the sideways force exerted by the propeller there is always a tendency for the right-handed single-screw ship to turn to port when going ahead. Hence it is usually found that her turning circle is of smaller diameter when turning to port than when turning to starboard under similar conditions of speed and rudder angle.

Effect of turning on speed

The effect of the drag of the rudder and the sideways drift of the ship will result in a progressive loss of speed while turning, even though the shaft revolutions are maintained at a constant figure. Up to 20° of alteration of course the reduction of speed may not be very great, but between 20° and 90° the speed usually drops rapidly. After 90° the speed may continue to fall slightly, but it usually remains more or less steady. The rate of deceleration depends upon the initial speed of the ship and the angle of rudder applied, and it varies greatly between different types of ship. Data for various classes of H.M. ships are given in B.R.45(4), *Admiralty Manual of Navigation*, Vol. IV, and are also supplied to each ship.

Very roughly, most warships when under full wheel will have lost about a third of their original speed after turning through 90°, and their speed will then remain steady as the turn continues. The figures for an average freighter are similar to those for a heavy warship.

An accurate estimate of the deceleration caused by a turn is helpful when manœuvring in company, particularly when the ship has to turn through a large angle to take station in a column.

The time taken to turn through a given angle depends on the initial speed and the angle of rudder applied; usually the faster the speed and the greater the rudder angle the sooner will the turn be completed. Times of various turns at different speeds and rudder angles are given in B.R.45(4) and are also supplied to individual ships. How this data can be used when taking up and changing station is discussed in Chapter 14.

Turning trials

To obtain data on a ship's turning performance at different speeds and angles of rudder, comprehensive turning trials are carried out by the Department of Ships in the first ship of each new class. One method of obtaining the data, that can be used by the ship's officers, is quite simple. A floating mark, or boat carrying observers, is placed in sheltered water with plenty of sea-room al]

round. The ship then approaches at a certain speed and applies a certain angle of rudder so that she will turn through 360° round the mark. At certain angles of turn (e.g. at 30°, 60°, 90°, etc.) a bearing and range of the mark is taken from the compass platform, and the exact time is noted. If observers are in the boat they take reciprocal bearings and ranges at the same instant. The process is repeated for different speeds and rudder angles. The method generally adopted by the Department of Ships is to use special observation stations on shore in a selected area.

Occasionally the ship's officers carry out turning trials in a new ship shortly after commissioning for the first time, but it is customary to accept the figures for the first of the class. From the data so obtained the ship's track under wheel can be plotted accurately on the largest desired scale, either when it is required to plan the intended track in advance (for example, when entering a harbour) or to establish the track accurately after an alteration of course. Methods of plotting the ship's track accurately on a large scale are described in *Admiralty Manual of Navigation*, Vol. I. These methods allow for the fact that after the ship is steady on her new course an appreciable time will elapse before she regains the speed she was making before the alteration of course.

Conditions for turning trials

Calm weather is necessary for the trials. The effect of wind and sea on turning performance is so marked that results obtained in rough weather will probably show confusing variations from the normal. If the method of plotting involves the use of a datum point that is either on shore or moored, there should be no tidal stream or current in the area. The trials should be carried out in a depth of at least 20 fathoms, or preferably in a depth of at least ten times the ship's draught, in order to avoid shallow-water effects. Special trials may be carried out in shallower depths to determine their effects on the turning performance.

After the trials a copy of the data is sent to the ship and should be placed in the Ship's Navigational Data Book.

Determination of the speed at any point in a turn

The speed remaining at a certain point in a turn can be calculated in the following way. From the turning trials data the ship's turning circle, for a given speed and rudder angle, can be plotted accurately. In the trials the time on completion of each 30° change of heading is noted during each turn. If the length of arc between two adjacent 30° points on the turning circle is measured, and divided by the time taken to alter course through that 30°, this will give the mean speed half-way between the two points. These mean speeds can then be plotted as a graph, against change of heading (P, Q, R, S in fig. 12–17). From the graph the speed remaining at any point in the turn can be read off. These graphs, or tables of speed remaining, usually appear in the turning trials reports.

Heel when turning

As explained earlier in this chapter, the initial heel when the wheel is put over is inwards, because the rudder force is acting at a point below the centre of

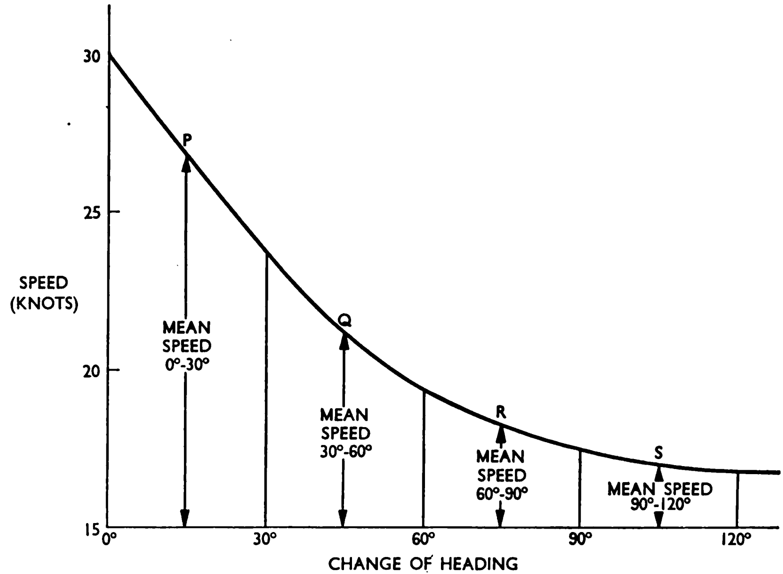


FIG. 12–17. Graph constructed to show the speed remaining at any point in a turn. The figure shows the graph for a ship at 30 knots turning with a rudder angle of 35°

gravity of the ship. As the ship begins to turn the centripetal force on the hull (which is greater than the rudder force), acting through water pressure at a point below the centre of gravity, overcomes the tendency to heel inwards and causes her to heel outwards. This outward heel is very noticeable in most warships turning at high speed. If the wheel is eased quickly the removal of the rudder force (see fig. 12–13) will increase outward heel, until the rate of turning decreases. If a power boat is carrying a heavy deck load the outward heel during a turn could be aggravated dangerously by quickly easing or reversing the wheel. Should an alarming heel develop, speed should be reduced instantly. In fast, shallow-draught craft, whose resistance to lateral movement is relatively small, there is considerable side-slip rather than outward heel, because the centripetal force on the hull is lessened. Therefore when turning at speed the rudder pressure causes such boats to heel inwards. In a fast motor boat the initial inward heel caused by multiple rudders at high speed may be violent.

Effect of reversing the inner screw when turning

When the screws on the inside of the turn are reversed at the moment of putting the rudder over, the effect usually will be to reduce the tactical diameter. The advance may or may not be affected. The speed of the ship will be drastically reduced as astern revolutions are worked up, and the time taken to turn through 180° will be correspondingly increased. Fig. 12–18 shows typical paths with full rudder and inner screws reversed, in comparison with the normal turning circles under full rudder. The circles are not greatly affected during the first quadrant, principally because the inner engines in turbine-driven ships take some time to run off their ahead revolutions and develop effective astern power.

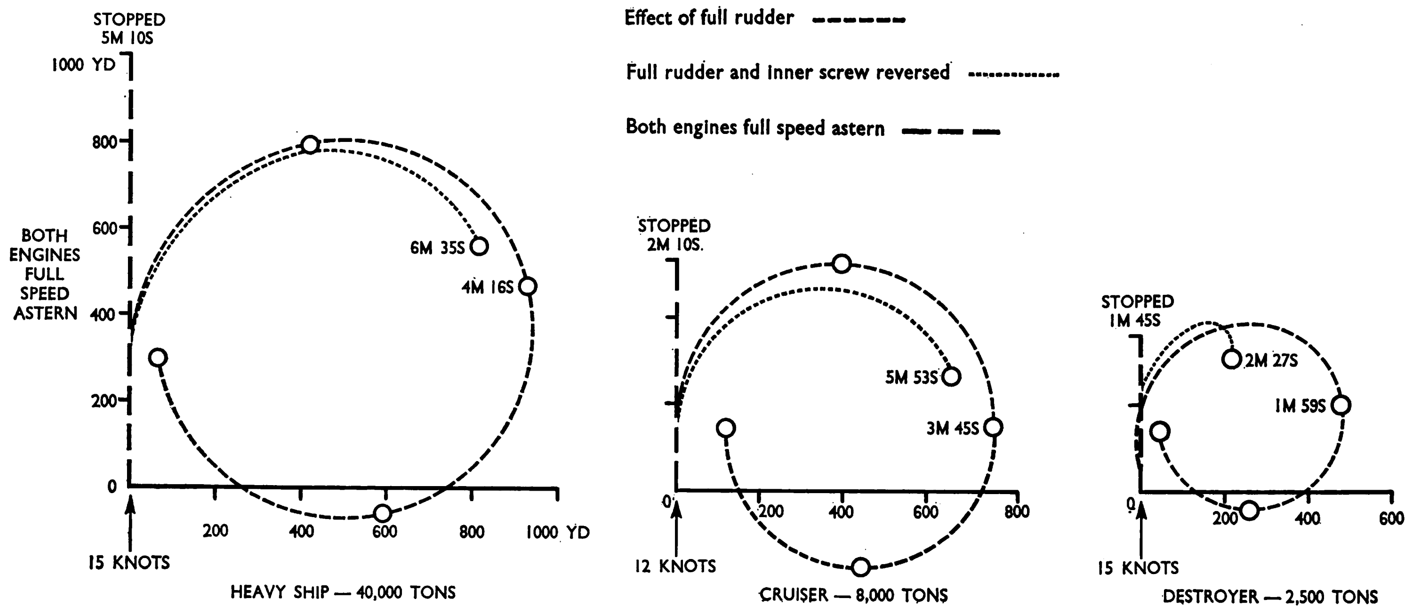


FIG. 12–18. Effect of going full speed astern on both engines, and also of putting the starboard engines only astern, in three types of ship. Typical paths and figures are given

Heavy ships will lose headway after turning through about 180°, and thereafter the tendency is often towards gathering sternway. Destroyers and frigates may lose headway after turning through 60° or so, and will consequently have a greatly reduced transfer. The distance covered before all way is taken off the ship, if both engines are put full speed astern instead of putting the rudder over, is also shown.

A captain should know the circumstances in which reversal of the inner screws will be advantageous in his ship. Where reduction in the turning circle is required and loss of speed is acceptable or desirable—for example, when negotiating a sharp turn after passing through breakwaters—the inner screws can often be reversed with good effect. When avoiding a danger ahead, however, the reduction in advance with inner screws reversed is usually so small when the ship is proceeding at any speed that no advantage would be gained, other than loss of headway. If a turn under full rudder appears unlikely to clear the danger it may be preferable not to risk a broadside encounter, but instead to take as much way off the ship as possible by going full speed astern on both engines.

Steaming with one engine stopped

The amount of rudder required to maintain the course will vary with individual ships and in different weather conditions. A heavy ship may require 10° of opposing rudder, and a destroyer considerably less. A smaller rudder angle will be required if the shaft can be trailed, but if machinery repairs are being carried out this will not normally be possible.

Steering by main engines

The procedure will vary according to circumstances and with the opinions of individual commanding officers. Some prefer a standard procedure whereby the same set of engines is always maintained at constant revolutions and the other set varied so as to maintain the course. When it is required to make good the best possible speed it will be preferable to keep the weather engines at constant revolutions and to decrease the revolutions on the lee engines as necessary to maintain the course.

ACCELERATION AND DECELERATION

Factors affecting gain and loss of speed

The following factors determine the acceleration powers of a ship:

1. *Inertia.* A heavy ship is slower both to gain and lose speed than a smaller ship with comparable engine power (see fig. 12–1).
2. *Shape of hull.* Of two ships of similar displacement the one with finer lines accelerates more rapidly and carries her way further than the one of fuller form.
3. *Power of propulsion machinery.* A ship with reciprocating engines responds more rapidly to engine orders than a turbine-engined ship. This shows particularly in the longer time taken to run down the turbines from a high ahead speed, even if maximum astern steam is applied. Some diesel-engined ships have non-reversing engines, so that to go astern the shafts must be

reversed through gearing. Such ships cannot stop engines when manœuvring, but merely put the gears in 'neutral', so that the shaft trails and any braking effect from the propeller is lost.

4. *Design of propellers.* The size and design of the propellers must be considered in conjunction with the propulsion machinery. Reciprocating engines driving large slow-turning propellers of coarse pitch produce a given shaft horsepower most rapidly. A large propeller acts as a considerable drag when slowed or stopped, and thus improves the rate of deceleration; when reversed, the effect of its astern revolutions is felt immediately.
5. *State of ship's bottom.* The drag of a foul bottom has more effect when decelerating than when accelerating from rest.

Rates of gaining and losing speed

A knowledge of the rate at which a ship gains or loses speed in different circumstances is invaluable when anchoring or when manœuvring in confined waters or in company. These rates depend chiefly on the displacement of the ship, her condition of loading, her draught, her horsepower, the size of her propellers, and the depth of water; the corresponding rates for one ship will differ largely from those of another, and the rates for a particular ship may change considerably with her condition of loading. It is customary to give the rate in the form *yards per knot*, e.g. if the rate is 100 yards per knot, the ship will take 500 yards distance to increase speed from, say, 10 to 15 knots.

When turning trials are carried out some data on acceleration and deceleration are also usually obtained. These additional data come under the heading of Starting and Stopping Trials. The information is basically as follows:

Gaining speed. The time taken and distance required to reach a certain speed when:

1. Proceeding ahead from rest,
2. Increasing speed when under way,
3. Regaining the original speed after a turn.

Losing speed. Similar data for:

1. Reduction of revolutions when steaming ahead,
2. Stopping engines when steaming ahead,
3. Reversing the engines when steaming ahead.

Typical figures for gain and loss of speed

Some rough figures for various types of ship are given in the following table:

Heavy Ship (e.g. Carrier)	*Time, in minutes*	*Distance, in cables*	*Yards per knot*
To attain 10 knots from rest	8	11	220
To lose way after stopping engines at 10 knots	$8\frac{1}{2}$	6	120
To lose way after reversing engines to half-speed astern at 10 knots	4	4	80

Cruiser	*Time, in minutes*	*Distance, in cables*	*Yards per knot*
To attain 14 knots from rest	5	8½	120
To lose way after stopping engines at 14 knots	10	8	115
To lose way after reversing engines to half-speed astern at 14 knots	5	3½	50
Frigate			
To attain 20 knots from rest	3	6	60
To lose way after stopping engines at 20 knots	2	4	40
To lose way after reversing engines to half-speed astern at 20 knots	1½	2	20

When increasing or decreasing speed by changing the ahead revolutions, the rate of acceleration or deceleration is affected by so many factors and varies so much in different parts of the total speed range that it is difficult to recommend any practical method of allowing for it accurately when manœuvring. It is common practice to use a standard figure for the ship under all conditions (e.g. 100 yards per knot for a heavy ship, 50 yards per knot for a frigate or destroyer). It must be realised that this method may prove extremely inaccurate in certain circumstances, and the shiphandler should be prepared to make bold and rapid adjustments to speed during a manœuvre if it appears that the estimate is wrong. An example of the practical application of the method when taking up station is given in Chapter 14.

FACTORS AFFECTING SPEED

Foul bottom

If a ship lies for long in harbour, particularly in a tropical harbour, her bottom becomes fouled by weeds, barnacles and other marine parasites or growths, and the speed attainable with a given number of revolutions is reduced. The extent of fouling depends largely on the locality of the harbour, being much worse in some harbours than in others even within the same area. Steaming at high speeds or lying at anchor in a fresh-water river reduces the amount of fouling.

The loss of speed caused by fouling can be given roughly as a fixed percentage of the clean-bottom speed, over the whole speed range. The effect is approximately the same for all classes of ship. For example, the growth accumulated during 6 months in average tropical waters would cause a reduction of about 10 per cent. Under these conditions a 30-knot ship would have her maximum speed cut to about 27 knots, while normal revolutions for 15 knots would give only 13½ knots through the water.

If docking is impossible, a considerable improvement in speed can be obtained by listing the ship and scraping the exposed hull, because the greater part of the growth is near the waterline. The actual speed obtained at different revolutions should be checked frequently, especially in tropical waters, because any estimate of loss due to fouling can only be a rough guess.

Shallow water

When a ship is steaming in shallow water the gap between the ship's hull and the bottom is restricted, the streamline flow of water past the hull is altered and the result is seen as a greatly increased transverse wave formation at the bows and again at the stern. In fact, the increased size of the stern wave is a sure indication of the presence of shallow water. The energy expended in the waves formed by the ship is a loss from the power available to drive her, and therefore in shallow water her speed is reduced. Furthermore, the restricted flow of water past the stern reduces propeller efficiency, which also tends to reduce her speed. Usually, the higher the speed the more pronounced is the reduction of speed. In extreme cases, and particularly in ships of low freeboard aft, the quarterdeck may be flooded by the stern wave.

The effect of shallow water on handling the ship is discussed further on page 277.

GOING ASTERN

When a ship is moving astern the pivoting point moves to a point well aft. Thus the turning moment of the rudder is greatly reduced as compared with the situation when moving ahead. Also, the propeller slipstream no longer plays upon the rudder. For these reasons a ship does not steer nearly so well astern as ahead, particularly at lower speeds. In a twin-screw or multiple-screw ship this defect can be overcome to a certain extent by using the propellers on either side. However, in a single-screw ship the difficulty is accentuated, because in going astern the screw kicks the stern to port, and in some cases the use of full starboard rudder fails to counteract this. In calm weather a single-screw ship is best manœuvred astern by pointing the stern to starboard of the desired direction, gathering plenty of sternway and stopping the engines. The rudder should then steer the ship.

In general, one cannot rely on the rudder to control the steering when making a stern board. Even when there is ample sea-room and when handling a ship, such as a destroyer, that is known to steer well astern, it must be remembered that a heavy strain is brought on the steering gear and that there may be difficulty in righting the rudder.

The size of the turning circle when moving astern is generally much greater than at the same speed ahead.

FACTORS AFFECTING THE SHIP'S HANDLING QUALITIES

Draught, trim and loading

A moderate reduction in the draught of a warship, as occurs when her fuel is low, usually causes a slight increase in her tactical diameter. In a merchant ship such as a freighter or tanker the difference between her turning qualities when lightly laden and when fully laden is very marked. When deeply laden a freighter has a much larger turning circle than when lightly laden, and she is more sluggish in answering her rudder.

Trim by the stern usually increases the tactical diameter, but helps a ship to keep her course more easily when on a steady course. When trimmed by the bows her turning circle is likely to be decreased; she does not answer her wheel as readily as usual, and once she has started to swing it is more difficult to check her. The effect of trimming is to move the ship's pivoting point towards the deeper end.

List

The effect of a list is to hinder a turn in the direction of the list and assist a turn away from it. A list to port decreases the tactical diameter of a ship turning to starboard, and vice versa.

Speed

Other things being equal, the higher the speed the greater will be the tactical diameter. However, this effect is not so pronounced in modern designs of H.M. ships as formerly, because rudders are more efficient at high speeds and at large angles.

Wind

General effects. In most ships the pivoting point is well forward when moving ahead, so that the pressure on the greater exposed area abaft this point tends to turn the ship into the wind. When going astern, the pivoting point moves aft and the stern tends to fly into the wind. The degree to which these effects are felt depends largely on the shape and disposition of the ship's superstructure. For example, a ship with a very high forecastle and much of her top-hamper forward is not affected a great deal when going ahead, but her stern seeks the eye of the wind rapidly as soon as she gathers sternway. The effect on the ship's turning circle usually is to expand the curve in the two quadrants in which her bows are turning away from the wind, and to contract it elsewhere. When turning away from the wind the ship is sluggish in answering her rudder. She may be carrying lee rudder already to keep her on her course, so that in order to start the turn more wheel than usual must be applied. When avoiding a danger ahead remember that the advance will be greater when turning away from the wind.

Wind effects are felt more strongly when speed is slow, and in a merchant ship when she is lightly laden. As ahead speed is reduced the bow usually falls off the wind more and more rapidly until, when the ship has lost all way, she lies approximately beam-on to the wind.

Effect when turning at rest. When turning at rest in calm weather a ship pivots about a point somewhere between her centre of gravity and the centre of area of her underwater profile. This point is normally somewhat forward of amidships, but it moves forward or aft with trim by the bow or stern respectively. Under the influence of wind the attitude of a ship when stopped depends on the relation between the area exposed to the wind before and abaft the at-rest pivoting point. Usually a warship lies with the wind within 20° of the beam, and when settled there requires a greater turning moment than normal to start her turning at rest.

Drift. Any ship drifts to leeward under the influence of wind, the rate increasing progressively with loss of way and with an increase in the angle of wind from the fore-and-aft line. When stopped and beam-on to the wind, the ship, as she drifts to leeward, begins to transmit her motion to the water surrounding her. The rate of drift increases up to a point at which both the ship and a body of surrounding water are moving bodily to leeward. Immediately the ship moves ahead or astern she will then enter water that is not drifting and so will reduce her own rate of drift to leeward.

Effect of sea. In the open sea a strong wind is, of course, accompanied by heavy seas or swell. Their effects on the handling of the ship are discussed in Chapter 15.

Current and tidal stream

Clearly the ship's handling qualities are not affected in any way if the whole body of water covering the area in which she is manœuvring is moving at a constant speed. In narrow waters, allowance must be made for the distance the ship will be moved by the stream during a manœuvre. But it frequently occurs in confined waters that the stream differs considerably within a small area, so that the bows may be exposed to quite a different current from the stern. The effects of current and tidal stream when handling the ship in narrow waters in various situations are discussed more fully in Chapter 13.

Shallow water

The effects of shallow water on the speed of the ship and on the flow of water past the hull when moving ahead have already been described. These effects may become excessive if the depth of water is less than one-and-a-half times the draught, particularly if the ship enters such water at high speed. She may become directionally unstable and fail to answer her rudder at all, and the draught aft may increase so greatly as to cause the propellers to touch bottom. The effects are likely to be particularly pronounced in ships where the propeller slipstream does not play directly on to the rudder. The effects of shallow water on steering in restricted waters such as canals or rivers are usually worse than in the open sea, and are more likely to have dangerous results. The only way to regain control is to reduce speed drastically at once.

When manœuvring at slow speed or turning at rest in a confined space in

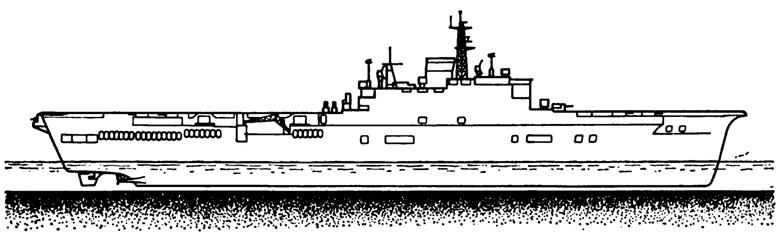


FIG. 12–19. Clearance between keel and sea bottom—a large aircraft carrier in a shallow harbour

shallow water, the expected effects from the rudder and the propellers may not appear. Water cannot flow easily from one side of the ship to the other, so that the sideways force from the propellers may in fact be opposite to what usually occurs. Eddies may build up that counteract the propeller forces and the expected action of the rudder. If the attempt to turn at rest in shallow water with ahead revolutions on one shaft and astern on the other fails, or the turn is very sluggish, the situation will almost certainly become worse if the revolutions are increased. Stopping the engines to allow the eddies to subside, and then starting again with reduced revolutions, is more likely to be successful. The extremely small clearance between keel and bottom in many harbours becomes obvious if a heavy ship in shallow water is drawn out to scale, as in fig. 12–19, which shows a carrier drawing 32 ft in a depth of 6½ fathoms, a situation that is not uncommon.

SPECIAL TYPES OF RUDDER AND PROPELLER

To conclude this chapter a brief description of a number of unorthodox types of propeller and rudder is given. Some of these have been fitted to H.M. ships or boats, as mentioned below.

Kitchen rudder

This consists of a pair of vertical plates that can be moved around the propeller of a boat so as to control the flow of water from it. The rudder is described in Volume II. The advantage of the gear is that it enables the boat to go astern without reversing the propeller. This is done by closing the plates so as to form a semi-circle abaft the propeller. In addition, the two plates, both when closed abaft the propeller and when open, can be moved round the propeller from starboard to port, so controlling the direction of the stream from it and enabling the boat to manœuvre well in confined spaces. A number of ships' power boats have been fitted with Kitchen rudders.

Active rudder

A submerged electric motor is built into a special rudder and drives a small propeller fitted in the rudder. The propeller produces a stream in the plane of the rudder; its rotation can be reversed and it turns with the rudder. Usually the rudder can be turned through 90° or more, so that a direct sideways force can be applied at the stern of the ship. At slow speed the Active rudder (as designed by Pleuger & Co., of Hamburg) permits a very good control of steering and gives a ship a very tight turning circle. Some coastal minesweepers have been fitted with it.

Jet propeller

The first application of mechanical power to ships consisted of an installation by means of which water was drawn by a steam-driven pump through openings in the bows and ejected through nozzles in the stern. This system proved far less efficient than the paddlewheel and the screw propeller, and is now only used in certain specialised craft where efficiency of propulsion is of secondary importance compared to other requirements.

Paddlewheels

This term is applied to a form of propeller which rotates about a horizontal transverse axis above the vessel's waterline, and consists of a wheel having paddles or *floats* attached to its periphery. The paddles may be fixed or *feathering*, the latter giving better performance but involving high initial costs and maintenance. The paddlewheel held undisputed sway during the first half of the last century, but was superseded for ocean work by the more convenient screw propeller. Paddle tugs are still maintained in some dockyard ports. These are invariably *side-wheelers*, and are fitted with feathering floats.

Vertical axis propellers

These are virtually feathering paddlewheels set in the bottom of a vessel on a vertical axis. The degree of feathering can be controlled so that the resultant of the blade forces acts in any desired direction, with the result that the vessel can be both propelled and steered. Though the efficiency is less than that of comparable paddle or screw installations, this arrangement gives remarkable steering control at slow speed and is thus suitable for craft operating in crowded and restricted waterways. The design in most common use is the Voith-Sclmeider or Kirsten Boeing.

Controllable-pitch propellers

These are propellers in which the pitch can be altered so that the full power of the machinery can be developed at optimum efficiency and under all conditions of service, e.g. in bad weather with a foul bottom, or when towing. The pitch can also be reversed to enable the ship to go astern without reversing the direction of rotation of the main engines. Such a feature gives unequalled rapidity of manœuvre and is of advantage in providing a convenient means of reversing internal-combustion (including gas-turbine) machinery. It is also of advantage in making possible very low controlled speeds, which are not otherwise obtainable with powerful internal-combustion machinery. Because of the shape of the blades near the boss and the larger size of the boss itself, there is a small loss of efficiency compared with fixed-pitch propellers at high speed.

The fitting of such propellers is at present restricted to some diesel-engined frigates, tugs, minesweepers and certain specialised types of ship.

CHAPTER 13

Handling Ships in Narrow Waters

In the last chapter we have seen how a ship should react to her rudders and propulsion system in different circumstances. How to apply this knowledge practically to the problem of manœuvring the ship in narrow waters and of berthing her in harbour is described in this chapter.

PREPARATION

A ship's handling qualities

On assuming a new command an officer should study all the information available in the Captain's Ship's Book and Navigational Data Book or elsewhere about her steering and propulsion systems, about previous experience of the ship's handling qualities and about any peculiarities of her construction, such as projecting screws or sponsons or overhanging superstructures. All this information will help him to form a complete idea of the ship's character that will improve his judgment as he handles her. He should take the opportunity as soon as possible of practising various manœuvres in open waters such as dropping and picking up a lifebuoy, turning into and away from the wind, steering at slow speed and with sternway, and turning at rest.

Importance of a plan

A sound plan is the essence of all successful pilotage. Having decided on a plan, the Captain should discuss it with his Navigating Officer and with any other officers concerned, e.g. the Executive Officer and Engineer Officer, so that it is clearly in their minds as the manœuvre is done and the Captain's intention at each stage is understood by all. If circumstances prove different, however, from those envisaged in the plan, an officer must be prepared to modify his plan or even abandon it altogether. Shiphandling is a practical art that cannot be done by rigid drill, and quick adaptability to a change in circumstances is a necessary quality in the shiphandler.

An essential feature of the plan for any manœuvre is a forecast of what will be the effect of the wind, current or tidal stream. Clearing bearings should be worked out so that the Navigating Officer can ensure that the ship does not drift unobserved into shoal water during the manœuvre.

Judgment of speed and distance

When there is no wind or tidal stream, speed can be judged by watching some object floating alongside, provided it is not affected by the wash of the propellers or the movement of the ship. In a wind or tidal stream, however, the movement of the ship must be observed by watching transits on shore, because it is the speed *over the ground* that is important. In an open anchorage, particularly at night, small pieces of wood thrown into the water near the bridge can be used to show when the ship has lost her way through the water.

Judgment of distance is much affected by the observer's height above the water; from a high bridge objects appear to be much nearer than from a low one.

When approaching a berth the direction of the ship's head in relation to anything ahead (a jetty, for example) is best estimated by standing amidships on the bridge so that the stem marks the fore-and-aft line. When conning from the wing of the bridge (or from the island in an aircraft carrier), some object in the ship lying directly ahead should be used as a mark instead of the stem.

Precautions

Critical situations may arise very suddenly when manœuvring in narrow waters, and to cope with them quick action is necessary. Such situations may be caused by an error of judgment, an unexpected manœuvre by a nearby ship, failure of engines or steering gear, misinterpretation of an engine or wheel order, a squall or shift of wind, or a wrong forecast of the strength or direction of the tidal stream.

To guard against failure of the engine-order telegraphs and the siren, they are always tested as a routine before the ship gets under way; but they should also be tested before a ship approaches pilotage waters after an ocean passage.

If a wheel or engine order has been misinterpreted it is best to order the wheel amidships, or stop the engine, before again giving the correct order. Experience has proved that the mistake will be corrected more quickly in this way than by reiterating the original order.

Generally speaking, ships should always be handled in narrow waters at slow or moderate speed; excessive speed is unseamanlike and may well lead to confusion and accident. This does not mean that the engines should always be confined to slow speed; in single-screw ships particularly, some manœuvres necessitate the propeller being driven at high speeds; it is the speed of the ship through the water that must not be excessive.

When manœuvring in a harbour both anchors should always be ready for letting go immediately. If the way of a ship has to be checked by her ground tackle in an emergency, both anchors should be let go rather than one, because it is better to lose both anchors, if this will avert a collision, than to save one and suffer a collision.

Astern power in many warships is a weak point. Although the design of engines and propellers is the governing factor, it is possible to vary the power by the number of boilers connected, in the case of a steamship, and the number of diesel engines connected to each shaft in the case of a diesel ship. Before manœuvring in harbour it is seamanlike to ensure that an adequate reserve of power is available.

Accidents can often be prevented by the quick and intelligent use of hawsers. Men should be trained in the expert handling of hawsers and heaving-lines, and these should always be ready at hand.

CONTROL AT SLOW SPEED

It should be fairly evident, from the description given in the preceding chapter of propeller and rudder effects and of how these effects are influenced by outside factors such as the wind, how a ship will handle at slow speed.

Generally, a ship continues to steer well so long as her propellers are turning ahead, however slowly. Thus it is best, particularly in a heavy ship, to take most of the way off the ship early, so that the propellers can be kept turning slowly ahead in the final stages of the approach to the berth. If he fails to do this, the shiphandler may be obliged to put the engines astern—and hence lose control of the steering—just at the most delicate stage of the manœuvre. This point underlines the advantage of controllable-pitch propellers, which can be kept going at very slow ahead or astern pitch, so providing good control at slow speed. One may be obliged occasionally to keep a relatively high approach speed in order to overcome the effect of a cross current or wind in the approach to a berth.

In a quadruple-screw ship, if the telegraphs fitted allow, it is possible to keep control at slow speed by keeping the two inner propellers going slow ahead and moving the outer propellers ahead or astern as required. This is equivalent to using three screws, and in a triple-screw ship the same effect can be obtained by keeping the centre shaft going slow ahead. In some ships prolonged running of astern turbines may damage the machinery.

A stern wind causes a ship to carry her way further than normal, and a head wind slows her down more quickly. This factor will affect the light-draught ship with a high superstructure far more than a heavy deep-draught ship. For all ships the effect of a current or tidal stream is usually much more noticeable than that of the wind; it will require a very strong wind indeed to counteract the effect of quite a moderate current.

When reducing speed, the possible effects of shallow water (as described in the previous chapter) must be kept in mind. For instance, when entering solid-walled pens most of the way should be taken off the ship before the propellers reach the line of the entrance, for their effects may be nullified by the restricted and shallow water inside the pens.

TURNING IN A CONFINED SPACE

The most important point to remember when turning in a confined space is how the pivoting point of the ship changes position when moving ahead or astern, and the resultant effect if there is any wind. Provided there is a little room in which to gain head- or sternway, the shiphandler should be able to take advantage of the wind and use it to help turn the ship. In a single-screw ship, in certain circumstances, it may be said in advance that she will turn readily one way—that is, either to port or to starboard—and that it will be difficult or practically impossible to turn her the other way.

Single-screw ship in calm weather

Assuming there is no wind, the best way to turn a ship with a single right-handed propeller in a confined space is to starboard.

First put on starboard wheel and go ahead on the engine. The wash from the propeller, acting on the rudder, will then swing the stern to port even before any appreciable headway is gathered. As the ship moves ahead the rate of swing will increase more and more swiftly. This movement should be continued until the sea room available dictates that way must be checked. Now go astern at high power and, as soon as the way is almost checked, reverse the wheel to hard

a-port. The sideways force from the propeller will immediately act to pull the stern to port and so help to continue the swing. As soon as sternway is gathered the effect of the rudder will enhance this tendency. Continue the movement astern as far as possible. Then put the engine ahead and the wheel immediately to hard a-starboard. Continue to 'back and fill' in this way until the turn is completed (fig. 13–1).

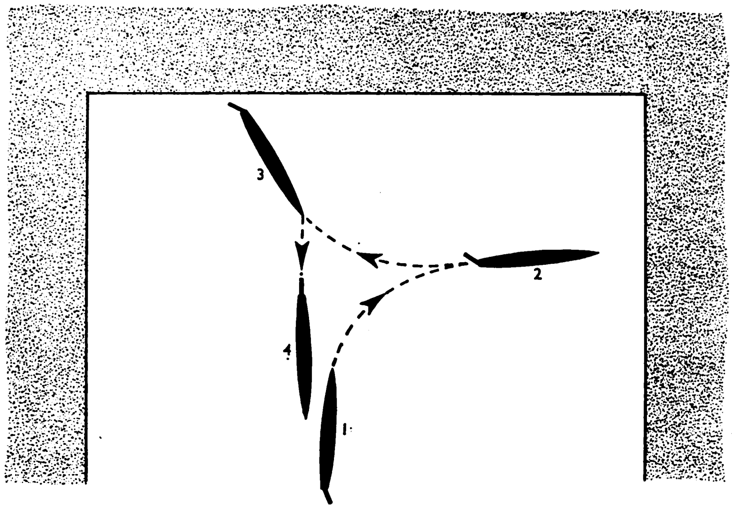


FIG. 13–1. Turning short in a right-handed single-screw ship, with no wind

In calm weather it is not possible to turn the average single-screw ship short round to port, owing to the contrary swing that develops as soon as the engine is put astern. Some single-screw ships however have a small high-speed propeller that develops very little sideways force, and in such ships a turn short round to port may be practicable when there is no wind.

Single-screw ship in a wind

Much depends on the direction of the wind relative to the ship throughout the manœuvre, and in single-screw ships one should remember these points:

1. The stern seeks the wind when the ship is moving astern.
2. When stopped, or nearly so, the ship tends to turn broadside-on to the wind.
3. When making a stern board the rudder has little effect until the ship has gathered considerable sternway, and then possibly only if the propeller is stopped.
4. The sideways force from the propeller is felt most when the ship is stopped or moving slowly and is proportional to the rate at which the propeller is revolving.

It follows that in a strong wind it may be easier to turn a single-screw ship short round to port than to starboard. Suppose that initially there is a strong wind from the starboard beam, and the shiphandler attempts to turn to starboard in a confined space (fig. 13–2). Consider what will happen if he loses headway

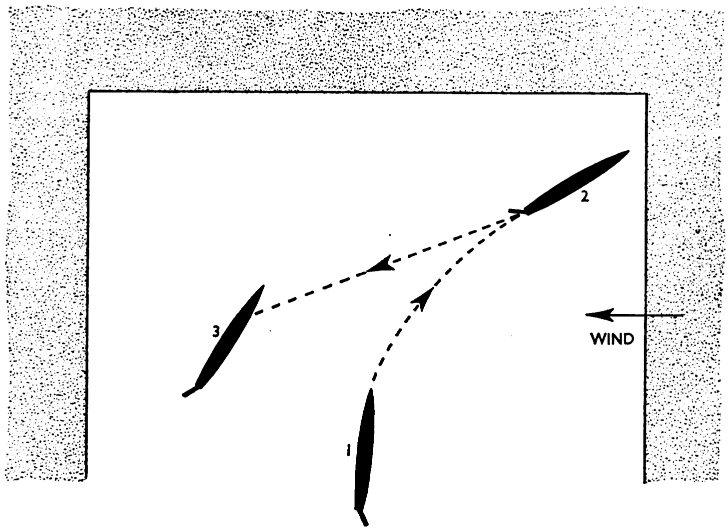


FIG. 13–2. Turning short in a right-handed single-screw ship, with wind initially from the starboard beam—*wrong method*

before the wind has been brought round on to the port bow (position 2). Now when he goes astern the tendency of the stern to seek the wind counteracts the sideways force of the propeller and he soon finds himself almost back where he started (position 3), except that by this time he will probably be further downwind.

If, instead, he starts the manœuvre by going ahead with full port rudder to position 2 (fig. 13–3), when he goes astern the sideways force of the propeller will be overcome more and more as the ship gathers sternway and the stern seeks

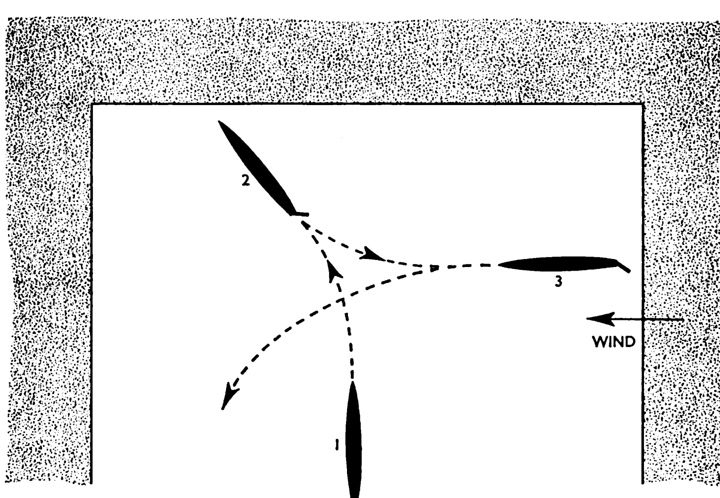


FIG. 13–3. Turning short in a right-handed single-screw ship, with wind initially from the starboard beam—*right method*

the wind, so that the ship reaches position 3. From here it is simple to go ahead with wheel hard a-port and complete the turn.

It would be tedious to consider various directions of wind and how they would each influence the problem of turning a single-screw ship round short. Considering the facts already mentioned, the officer in command of a single-screw ship will be able to work out the best course of action under the prevailing circumstances. In general, it will be found that the single-screw ship can be turned short *away from the wind*, either to port or to starboard; but she can be turned *into the wind* only if space permits headway to be maintained until the wind has been brought across on to the opposite bow.

Multiple-screw ship

The forces acting on the ship (and how these forces are modified in shallow water) when the screws are put ahead on one side of the ship and astern on the other are described in the previous chapter.

When turning in a confined space in a multiple-screw ship, it is usually advantageous to gather slight head- or sternway if space allows, as it is in a single-screw ship. This applies especially if the ship starts from the natural attitude of lying stopped with the wind on the beam. It is often found that the maximum rate of swing is achieved if the ship is kept moving ahead slowly while she is turning into the wind, and astern when turning away from it. The most effective position for the rudder is normally hard over in the direction of the turn, so long as the screws on at least one side are going ahead.

Triple-screw ships turn most readily when the centre propeller is kept turning ahead so as to throw its slipstream on the rudder, while the outer propellers are worked as necessary. If the centre propeller is left-handed it can be reversed occasionally without hindering a turn to port, but should not be reversed during a turn to starboard.

Aids to turning in a confined space

The most usual way of assisting a ship to turn in a confined space is to employ tugs (see page 316). A simple method that is always available is to use an anchor. A description of how to turn short on an anchor is given on page 293.

ANCHORING AND MOORING

If she is to anchor or moor, the ship will in most ports be allocated a particular berth by the shore authority. In unfrequented havens she may select one for herself, in which case the Captain must consider such points as the depth of water, range of tide, holding ground, prevailing weather conditions, proximity of landing places. A full discussion of these points is given in the *Admiralty Manual of Navigation*, Vol. I, as also is the method of piloting the ship so as to anchor her in a predetermined position.

Swinging room when at anchor

A ship at single anchor requires more room than one moored, as explained in Volume I. In deciding the radius of the swinging circle there are two

considerations: first, the proximity of fixed dangers such as shoal water and other charted objects such as rocks or piers; and secondly, the proximity of nearby ships at anchor that are themselves swinging round in their berths.

Distance from charted dangers

The safe radius for a ship at single anchor should be established initially by considering only the proximity of charted dangers, and not other ships at anchor, whose nearness varies according to how they are swung. This radius may be obtained by adding the following three items:

1. The length of the ship, or class of ship, concerned.
2. The length of cable to be veered. Since there are few harbours where the possibility of strong winds can be ruled out, it is prudent to assume that the maximum amount of cable carried by the ship on any one anchor is actually veered.
3. A safety distance to cover such imponderables as the accuracy of the instruments used for fixing the ship in her berth, time-lag between the executive order to let go and the anchor reaching the bottom, and so on. This distance must depend on circumstances and may vary, say, from 20 to 200 yards.

Suppose a ship of length 510 ft, with 10 shackles of cable available on each bower anchor, comes to a single anchor. Her swinging radius should be:

1. Length of ship, 510 ft	= 170 yd
2. Maximum cable, 10 shackles	= 300 yd
3. Safety distance, say	30 yd
Radius	500 yd *or* 2½ cables

Her berth must not be less than 2½ cables clear of all charted dangers, but it is prudent to add at least one cable to this distance to allow a greater margin of warning time should the ship drag her anchor.

Distance from other ships

The radius of swinging circle arrived at by this method (2½ cables in the above example) ensures that if a number of ships of that class are berthed at *twice* the radius apart the following events can take place without danger or difficulty:

1. Two adjacent ships may swing towards each other and at the same time have their cables drawn out to their fullest extent. This is, however, most unlikely to occur, since if there is a strong wind or stream the ships will be lying parallel and drawing out their cables in the same direction; and if the ships swing in opposite directions it is probably because the tidal stream is on the turn and almost slack, and the wind at the same time light, so that their cables are not laid out towards one another.
2. A ship anchored in the line may weigh anchor alone without fouling the others.
3. A ship may approach and anchor in the line without finding an adjacent ship swung over the point where her anchor is to go.

Space in harbours is often scarce and therefore it is seldom that the distance apart of two radii to allow for the first of these three contingencies can be allowed. If the berths of adjacent ships are placed at one radius apart, however, both of the other two events can occur without difficulty. It is customary therefore to place the berths of similar ships at one radius apart. Ships must be on their guard against swinging towards one another, but the risk is small. However, if two ships of dissimilar classes are berthed next to one another the distance between their berths should be at least that of the radius required for the larger of the two ships.

Reduced swinging radius

If space is particularly restricted the radius can be reduced (so far as proximity to other ships' berths is concerned) by adding together only the ship's length and the amount of cable which it is intended to veer, plus a safety margin of 50 yd. In the case quoted above this would give:

1. Ship's length, 510 ft		= 170 yd
2. Cable out, say, 6 shackles		= 180 yd
3. Safety distance		50 yd
	Radius	400 yd *or* 2 cables

If similar ships are anchored at this radius apart the risks mentioned above must be accepted.

Swinging room when moored

The object of mooring ships is to conserve space, and the swinging radius may be taken as the ship's length plus a safety allowance of at least 20 yd, but preferably of 50 yd. For the ship mentioned above this would give:

1. 510 ft		= 170 yd
2. Safety distance		= 50 yd
	Radius	220 yd *or* 1·1 cables

At least one cable should be added to this radius for the berth from any charted danger. However, it should be remembered that each anchor lies at a distance from the stem that is comparable to the ship's length. For example, if the cables are middled with 5 shackles on each, then each anchor will be about 135 yd from the stem. If a number of ships are to be moored in line with their cables laid out along that line it will be impossible to berth the ships at one radius (e.g. 1·1 cables in the above example) apart, because the cables of adjacent ships would foul one another. In fact, ships of the size quoted would have to be berthed at least 1½ cables apart to avoid this. But in planning mooring berths this is not the only consideration. One must also arrange in most cases that any ship may unmoor independently whatever the direction of wind or stream. To avoid difficulty under any circumstances it is found that the berths will have to be even further apart, and thus the saving of space achieved by mooring is not very great unless a large number of ships are mooring together. The problems of unmooring are discussed again in Chapter 14.

Amount of cable to be veered

The amount of cable to be veered depends upon a number of factors, e.g. the swinging room, the type of cable and anchor in use, the strength of the wind, tidal stream or current, and the holding ground. Perhaps the most important point to emphasize is that the anchor—and particularly the present Service type A.C.14 anchor—is most efficient when subjected to a horizontal pull by the cable on the seabed. The aim should be to ensure that enough cable is veered to permit this condition to be met.

Most H.M. ships are supplied with forged steel cable, although a few are still in service with mild steel or wrought iron cable. Forged steel cable is approximately 40 per cent stronger than mild steel or wrought iron cable, and is lighter for a given length. Thus, in two similar ships in similar circumstances, each with the same amount of cable out, but one having wrought iron or mild steel and the other forged steel cable, the curves formed by the two cables in the vertical plane will be different. In the case of the wrought iron the bight or catenary will lie deeper in the water, and, incidentally, the ship will be nearer to her anchor. The forged steel cable will form a shallower catenary. Circumstances could arise in which in the one ship the wrought iron cable would be lying on the bottom at the point where it joined the anchor, thus exerting a horizontal pull on it, while in the other ship the lighter forged steel cable would be lifted off the bottom at this point and would exert its pull from an angle of several degrees above the horizontal.

To ensure that the cable exerts a horizontal pull at the anchor it may be necessary to veer more forged steel cable than would be the case with wrought iron or mild steel cable. This point is illustrated in the graphs shown in fig. 13–4. The curves show the minimum amount of cable which should be laid out in various depths of water to ensure a horizontal pull on the anchor. It will be seen from these graphs that to use a rough rule that the amount of cable out should be x times the depth of water, where x is a constant factor, is misleading. In the case of forged steel cable, one would need 13 times the depth of water in 5 fathoms, but only 6½ times the depth of water in 20 fathoms. A rough rule for forged steel cable that takes into account the formula on which the graph is based is as follows:

Amount of cable to veer in shackles is twice the square root of the depth of water in fathoms.

For example,

in	4 fathoms	you require	4 shackles
,,	9 fathoms	,, ,,	6 shackles
,,	16 fathoms	,, ,,	8 shackles
,,	25 fathoms	,, ,,	10 shackles

This rule allows a slight safety margin over the amount indicated on the appropriate graph in fig. 13–4. The graph is based on the requirement in calm weather, but with a tidal stream or current of 5 knots. In strong winds, or in exceptionally strong streams, more cable will need to be veered.

The holding pull of the anchor is normally expressed as a factor of its own weight. For example, the A.C.14 anchor will hold up to 10 times its own weight if the ground is good. In particularly good ground consisting of a mixture of sand, shingle and clay, it can rise to approximately 12½ times its own weight;

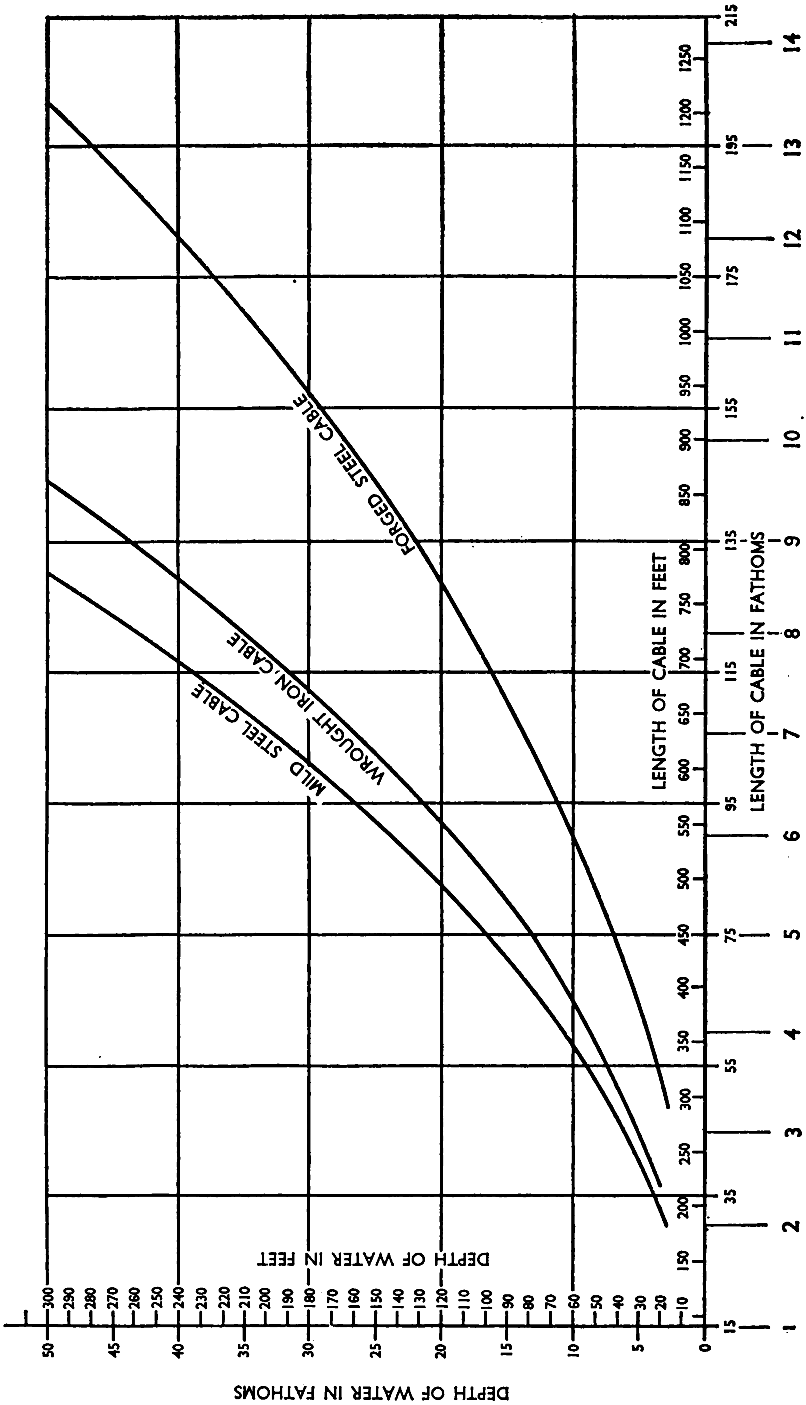


FIG. 13-4. Graph showing the *minimum* length of cable to be veered in relation to the depth of water

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while in poor ground of soft, silty mud it will drop to about 6 times. Some idea of the force likely to be exerted on the ship can be got from the table on page 179. Knowing his ship, the Captain can estimate the pull likely to be exerted on his anchor in the prevailing circumstances. He must then take note that if there is not sufficient cable out to exert a horizontal pull at the anchor, its holding pull will drop in accordance with the following scale:

Angle of inclination of cable at anchor	*Percentage of maximum holding pull of anchor*
5°	80
10°	60
15°	40

The exact conditions which give rise to these angles are not of much practical significance to the seaman. What is important is to realise what the consequences are likely to be if for some reason it is not possible or practicable to lay out enough cable to ensure a horizontal pull at the anchor.

Advice on what action to take when anchored in harbour in a gale or tropical storm is given in Chapter 15.

Approach to an anchor berth—reduction of speed

It is easier to anchor in the exact berth if steerage way can be maintained up to the moment of anchoring. If ships are anchoring in company it is essential to keep steerage way to permit ships to maintain station. For these reasons H.M. ships usually anchor with headway and lay out the cable under the ship. The alternative is to stop in the berth and then, having let go the anchor, to go astern laying out the cable ahead. The latter method is usually adopted by merchant ships, and it may be convenient for H.M. ships to anchor in this way in certain conditions—for example, when anchoring in a river where there is a strong current.

When anchoring with headway the speed when letting go should not be more than four to five knots over the ground. Too much speed may strain or part the cable, while too little will prolong the operation unduly. The following table gives a rough guide as to how speed is reduced when approaching an anchor berth in different classes of ship. Modifying factors such as wind and current must always be taken into account.

Distance from berth in cables	Orders to Engine Room for:			
	Aircraft Carrier (35,000 tons)	Cruiser (8,000 tons)	Cruiser (5,000 tons)	Frigate (2,000 tons)
15	12 knots	15 knots		
10	8 knots	10 knots		
8			10 knots	
5	Stop engines			10 knots
4				
3		Stop engines		
2			Stop engines	
1½				Stop engines
In berth	Half astern	Half astern	Half astern	Half astern

Approaching an anchor berth in deep water

When anchoring in very deep water it is customary to veer some cable (perhaps one shackle) during the approach. This is to prevent the cable from attaining a dangerous speed while running out after the anchor has been let go, and the anchor and cable from being fractured on striking the bottom. The ship's speed should therefore be reduced earlier to allow time for veering cable. It is advisable to stop engines, however, a little later than usual to allow for the drag of the anchor and cable through the water.

Approaching an anchor berth in a wind

If there is a wind during the approach that is not dead ahead, allowance for leeway must be made by adjusting the course so as to keep the ship on her head bearing or transit. The officer who is conning must be prepared to make bold alterations of course as the ship rapidly loses her way just before letting go, especially if the wind is on the beam. The weather anchor should normally be used so that the cable cannot foul the stem as the ship drifts to leeward after anchoring. If the approach has been made head-to-wind the ship's head is cast about ten degrees towards the side opposite the anchor just before it is let go, to ensure that the cable runs out clear on the windward side.

In a gale it is advisable to approach head-to-wind. After anchoring, the ship's head will pay off rapidly, so it is essential to cast her head slightly in the right direction before letting go. To give the anchor a chance of embedding itself and holding, a length of cable more than twice the depth of the water should be allowed at first to run out freely, and the cable should then be braked carefully to bring the ship's head back towards the wind without dragging the anchor.

Approaching an anchor berth in a stream

A high contrary wind is necessary to overcome the effect of a moderate stream, and it is therefore customary to anchor head-to-stream rather than head-to-wind. Anchoring with a following tidal stream (or current) of more than half a knot is not recommended, because a heavy strain is imposed on the cable, particularly when the ship is swung athwart the stream. In a heavy ship of deep draught it may be found that at this stage the cable-holder brakes cannot hold the cable, while there is not time to turn the ship head-to-stream with the engines before the cable has run out to a clench and parted.

If wind and stream are from opposite directions and it is impossible to approach so as to stem either, the shiphandler must estimate in advance how the ship will move after she has let go her anchor, and how the bight of cable will be laid out on the sea bed, and must then drop whichever anchor he considers will have the best chance of holding.

In a strong current or tidal stream the anchor should be let go with the ship stopped, and the cable should be paid out gradually as the ship drifts downstream in such a way as to keep her head-to-stream. Violent yawing in a strong river current can be checked by letting go both anchors spanned across the stream, but this procedure is obviously unsuitable for tidal waters, where each change of stream would put half a turn in the cables.

Action after letting go an anchor

When anchoring in less than 15 fathoms of water an amount of cable equal to twice the depth of water should first be allowed to run out freely to enable the anchor to embed itself. Thereafter the brake of the cable-holder or windlass should be applied so that the cable is kept growing at an angle of about 30° with the vertical. The brake should not be applied fiercely and the cable should not be snubbed; only sufficient brake should be applied to permit it to render if the cable becomes taut. When a stationary cable tautens and then slackens it is a sign that the ship has come to rest.

When anchoring with headway in company, ships should lay out their cables in a straight line from their anchors, way being reduced by the engines and not by the cable-holder brakes. A heavy strain on the cable not only tends to weaken or part it, but may also drag the anchor away from the correct berth. Anchoring with too much way on gradually weakens the cable, leading eventually to the risk of parting the cable and possibly causing dangerous accidents. If care is taken both on the bridge and on the forecastle when anchoring, the life of the cable will be increased and the ship's safety assured.

Approach to a mooring berth

The following remarks refer to *mooring* as understood in H.M. Service, i.e. with two anchors down and cables middled at a mooring swivel. This method of anchoring the ship, although giving reduced holding power when the ship is riding in any direction other than in the line of the anchors, is sometimes necessitated by restricted swinging room.

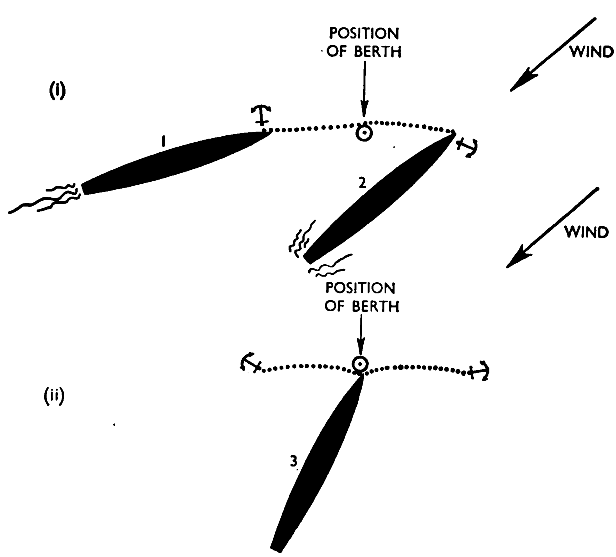

FIG. 13–5. Running moor. In (i) the ship lets go the first (weather) anchor in position 1 and the second (lee) anchor in position 2. In (ii) the ship is middled in position 3

It is important that the cable should be laid out from the first anchor in a straight line to the planned position of the second anchor, and that the ship's stem should be held as near as possible to this line when middling (fig. 13–5). The first anchor (normally the weather one) should therefore be let go with good steerage way on the ship, and the course steered should be such as to make good along the intended line of the anchors, up to the time of letting go the second anchor. In the approach the engines are stopped about one cable further on than would be the case in coming to a single anchor.

The work of middling should not be left entirely to the cable-holders. If there is a cross wind or current, one should work the engines so that the bows are kept on the line of the anchors. In calm weather, with no cross current, the engines should be used to gather slight sternway to assist the middling process.

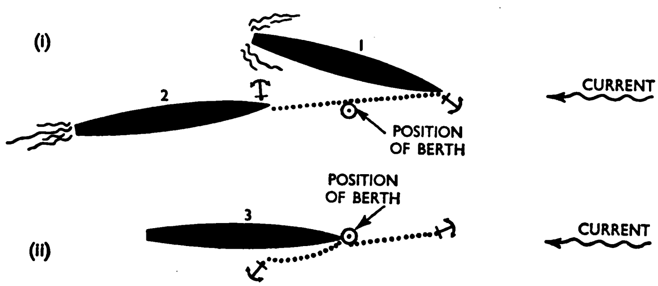

FIG. 13–6. Dropping moor. In (i) the ship lets go the first anchor in position 1 and drops astern to let go the second in position 2. From there she steams ahead to middle in position 3

Normally the line of anchors is selected with a view to stemming the current or prevailing wind. It is inadvisable to moor a heavy ship with a stream of more than half a knot under her. When mooring against a strong current it is sometimes preferable to execute a dropping moor (fig. 13–6). The upstream anchor is let go first. After letting go the second anchor (position 2), the ship can be steamed back towards the upstream anchor, thus reducing the strain on it when middling.

Turning short round an anchor

Letting go an anchor and holding it at short stay, and then steaming round it on a taut cable, is a very useful method of turning a ship where manœuvring room is limited. When doing this, however, two points must be borne in mind: first, that the anchor should not be let go where it may foul the ground tackle of other ships and moorings, or the cables of telegraph and telephone services; secondly, that the manœuvre must be made at slow speed and the cable tautened very gradually. The cable will be growing aft throughout the turn and so may be given a bad nip by the after edge of the hawsepipe, and it may then be parted by any sudden stress.

The wheel is first put over in the required direction, with the ship steaming slowly ahead, then the anchor on the side towards which you are turning is let go. The engines are stopped and sufficient cable to hold the bows is allowed to

run out on the brake (say, a length equal to about twice the depth of water), while the way of the ship is reduced and the cable gradually tautened. When the cable is taut the engines are put to slow ahead; and, with the wheel over, the ship is steamed round her anchor to the required direction.

When a wind is blowing it should be foreseen that the ship will always swing head-to-wind when finally the anchor is weighed, and that this may cause her to swing back towards her original heading.

Dredging an anchor

Towing an anchor at short stay in order to improve manœuvrability is sometimes called *dredging an anchor*. For example, when going alongside in an offshore wind, or when passing through a narrow entrance where there is a strong cross-stream, the ship lets go the anchor at slow speed as she approaches and drags it along the bottom. This has the dual effect of enhancing the control of the bow and of holding it upwind or upstream.

Weighing anchor

As the cable is hove in the ship will gather a certain amount of way towards her anchor which will help to break the anchor out of its bed. Single-screw ships usually require considerable room to turn, and in confined anchorages in calm conditions it is often best first to heave in cable to short stay, until there is just sufficient scope of cable out to prevent the anchor coming home, and then to steam round the cable to the required direction as described above.

When weighing in company, men-of-war usually first heave in to short stay before weighing to ensure that their anchors are broken out simultaneously when the order to weigh is given.

It is important to ensure that when the anchor is aweigh the bows will not pay off in the opposite direction to that in which you wish to turn. This can be done by first allowing the bows to pay off slightly in the wrong direction while shortening-in the cable, so that in the final stage of weighing the bows are given a very decided cast in the required direction.

When heaving in cable to weigh anchor, the cable may grow athwart the stem and so be subjected to a bad nip. When this occurs 'Avast heaving' should be ordered until the bows swing towards the anchor and the cable grows clear again. If this is not done a heavy stress will be imposed on the links and joining shackles of the cable as they pass across the stem, which may result in the cable parting or being severely strained.

Unmooring

Although the cables may give the impression of being clear, there may be turns some distance below the swivel. Before unmooring it is sometimes advisable to bring a strain on the cables by moving the engines astern, when any turns may clear. In order to bring a strain on both cables it may be found necessary to turn the ship cautiously in the direction of open hawse.

The lee, or downstream, anchor is invariably weighed first. With wind or stream across the line of anchors, start weighing the weather anchor immediately the lee anchor is off the ground, because the ship may swing into danger if she remains riding to eleven or twelve shackles of cable. (See also p. 349.)

BUOY BERTHS

The methods of sending the picking-up rope to a mooring buoy and of securing the bridles to the buoy are described in Volume II. This section is concerned with the handling of the ship while approaching and while securing in buoy berths. A description of the buoys and their moorings is given in Chapter 8. A ship can either secure head to a single buoy, or head-and-stern between a pair of buoys.

Approach to a single buoy

In calm weather with no appreciable wind or stream the ship is headed for the buoy at slow speed and brought to rest with one of the hawsepipes over the buoy so that the ends of the bridles can be lowered through it directly to the buoy

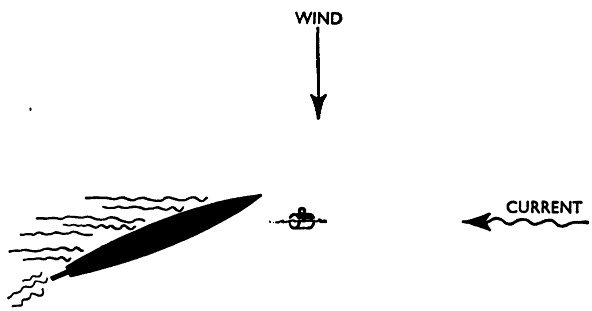

FIG. 13–7. Where to hold the ship while passing the picking-up rope if wind and stream are from different directions

jumpers. A plan must be prepared beforehand to enable speed to be reduced and the engines stopped and put astern at the appropriate distances from the buoy. It is advisable to take the way off the ship a little short of the buoy, while the picking-up rope is being passed, and then edge up to the buoy slowly. If there is any stream or current the ship should be headed into it, if possible. If this is not done it will be found that it is very difficult to hold the ship's bows near the buoy for a reasonable time while the picking-up rope is being secured. If there is a wind from one side or the other in addition to the stream, the ship should be headed upstream but slightly to windward of the direction of the stream, when it will be found that by keeping an occasional ahead movement of the engines and by the use of the wheel, the pressure of the stream can be made to balance the leeway and the ship held stationary by the buoy (fig. 13–7). Thus the presence of tidal stream or current can help by enabling steerage way to be kept during the process of securing.

If there is a wind but no stream it is usually preferable to head into the wind if possible; but if the wind is strong, it is difficult to prevent the bows falling off the wind when way has been lost. An approach directly downwind may be easier, particularly if the ship has a high forecastle or upperworks forward, because the stern seeks the wind whenever the engines are put astern. However, it is impossible to maintain this attitude once the picking-up rope has been secured, and it is difficult to shackle on the bridle until the ship has swung right round head-to-wind.

If there is no stream, but it is impossible to head into the wind while approaching because of lack of sea room, it is best to stop the ship not only to windward of, but short of, the berth (fig. 13–8). Starting from such a position it should be possible to keep the ship turning slowly into the wind with slight headway during the process of hooking on, while the boat carrying the picking-up rope will have a downward passage to the buoy. An alternative plan would be to turn short on an anchor into the wind from a point immediately to leeward of the buoy. This, however, involves the risk of dropping the anchor foul of the buoy moorings.

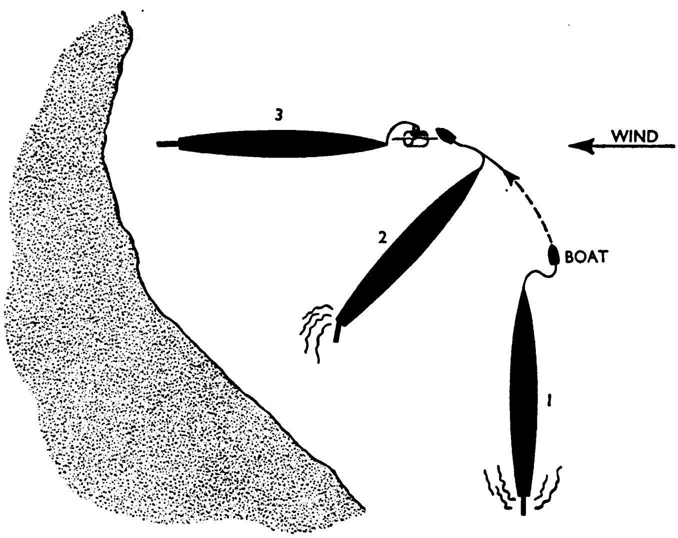

FIG. 13–8. Approach to a single buoy when there is insufficient room to approach upwind. 1. Stop and lower boat. 2. Turn into wind with slight headway. 3. Picking-up rope secured

When securing to a single buoy, it should not be assumed that the handling of the ship ceases as soon as the picking-up rope is hooked on. Engines may have to be used, particularly in a heavy ship, in order to keep the hawsepipe over the buoy while shackling on the first bridle.

An officer should not hesitate to use a tug when securing to a buoy if difficulty is foreseen, either because of poor handling qualities of a ship or because of the environment of the berth. This applies particularly to single-screw ships.

Slipping from a single buoy

If there is no wind, current or tidal stream when the buoy is slipped, the engines should be worked astern until the ship is well clear of the buoy before any attempt is made to turn in the required direction. Nothing is gained by turning with the buoy close under the bows, because not only is the ship's freedom of movement then restricted but the buoy may easily foul her propellers when she goes ahead.

If there is a wind the buoy will spring well clear of the ship when it is slipped and the ship's bows will start to pay off from the wind, so that it will then be

possible to go ahead on the engines without first moving astern, the rudder being used to swing the stern clear of the buoy if necessary. In a tideway, the ship can be cast in the required direction by her rudder before slipping.

Unless unavoidable, the sliprope should not be slipped when there is a heavy strain on it, because the slip may jump up and injure the man who knocks it off. The hauling end of the sliprope should be surged until there is little strain on it, and the slip then be knocked off.

In a small ship a sliprope may be rove from a point well aft in the ship if there is a stream running and it is necessary to turn on slipping. On letting go the bridle, the ship will swing right round bows-downstream, provided that the point in the ship where the sliprope is secured is abaft the centre of underwater pressure. It may be advisable to reeve a sliprope forward as well in order to keep the bows under control until it is time to turn the ship.

Securing between two buoys

Trots of mooring buoys for securing a number of ships head-and-stern are usually laid along the line of the tidal stream or prevailing current, so that, when securing between two buoys, difficulty is more likely to be caused by the wind than by the stream.

If it is possible to approach the head buoy directly in calm weather the manœuvre is simple. The ship is stopped as close as convenient to the head buoy and as nearly as possible along the line of the buoys, and boats can then be sent simultaneously with picking-up ropes to the head and stern buoys.

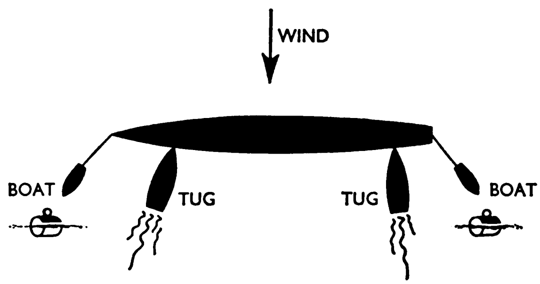

FIG. 13–9. Securing a heavy ship between two buoys with the wind from the beam

If there is a wind from the beam the ship must be stopped to windward of the berth to allow for the drift to leeward while the picking-up ropes are made fast. In a heavy ship a tug is necessary both forward and aft to control the rate of drift and to hold the ship in her berth while the bridles are secured (fig. 13–9). A small, handy ship may approach the head buoy downwind, if there is sea room, secure to the head buoy and then allow the wind to carry the stern round to the stern buoy. At first she must place the head buoy under her lee bow and must then control the rate of swing by working the engines (fig. 13–10).

Turning the ship when securing between two buoys

A common requirement in securing between two buoys is that, after entering the harbour and before securing to the buoys, the ship must be turned end-for-end so that she will be secured heading out of harbour. If there is room to

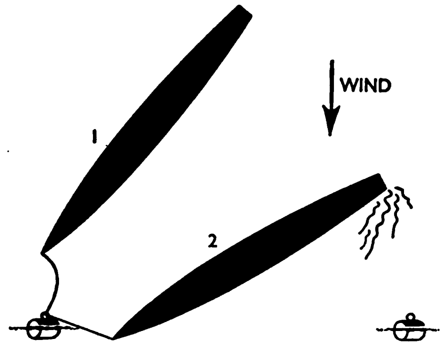

FIG. 13–10. Securing a small ship between two buoys with the wind from the beam

complete the turn before approaching the buoys, this may be done and the buoys then approached making a stern board, with allowance for the effect of the wind after the ship has been stopped by the berth. It is better either to complete the turn before approaching the berth, or to bring the ship up dead between the buoys and then turn at rest there. An attempt to start the swing in the final stage of the approach will require the most delicate judgment if the ship is finally to finish up in the correct position between the two buoys.

When it is intended to turn at rest in the berth, the bridge must first be placed in exactly the right position. Therefore it is essential to work out in advance the

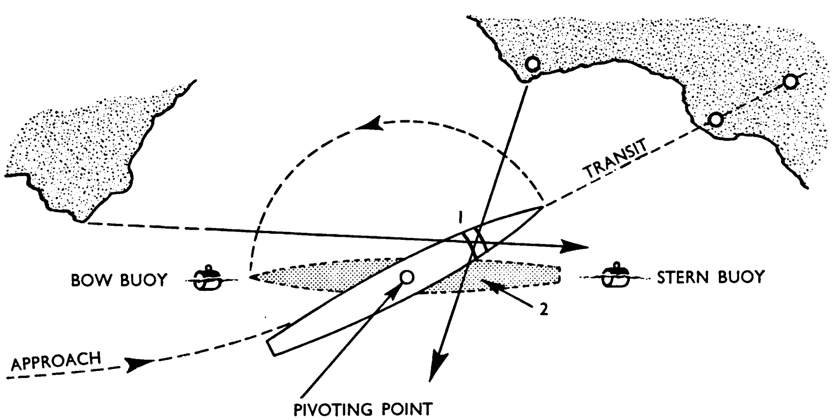

FIG. 13–11. Turning at rest between two buoys. 1. Initial position of the bridge, marked by cross bearings and a transit. 2. Final position of the ship

transits or bearings that will facilitate this. In doing so, remember that the pivoting point when turning at rest is not so far forward as the bridge, but more nearly amidships. In fig. 13–11 is shown an approach, uncomplicated by wind, in which the bridge is first placed in the correct position 1, so that after turning at rest the ship finishes up between the two buoys (position 2). It is advisable almost to complete the turn before sending away the boat from aft, to avoid the risk of fouling the screws with the stern picking-up rope.

It is important to realise that if the ship is not placed initially in the right position, one or other of the buoys will be fouled during the turn. If there is a wind blowing across the line of the buoys, allowance must be made for the

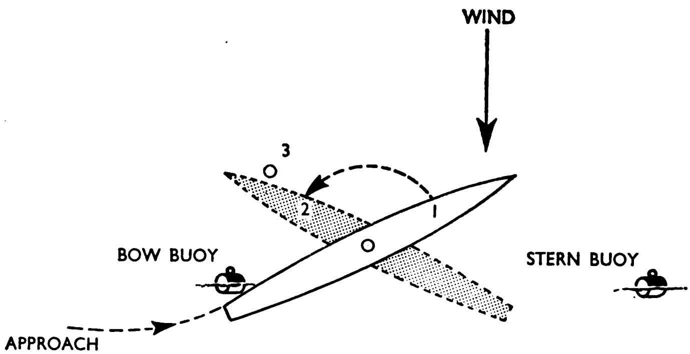

FIG. 13–12. Approach too close to bow buoy before turning at rest to secure between two buoys

bodily drift of the ship to leeward during the period of the turn. In fig. 13–12 the ship has been stopped in position 1 too close to the bow buoy. If the turn is continued beyond position 2 the bow buoy will be fouled. The only solution then would be to move the ship ahead until her pivoting point was in position 3, complete the turn there and then make a stern board to a point abreast of and to windward of the berth. Had the wind been from the opposite direction, it would have been necessary to start making amends by going astern from position 2.

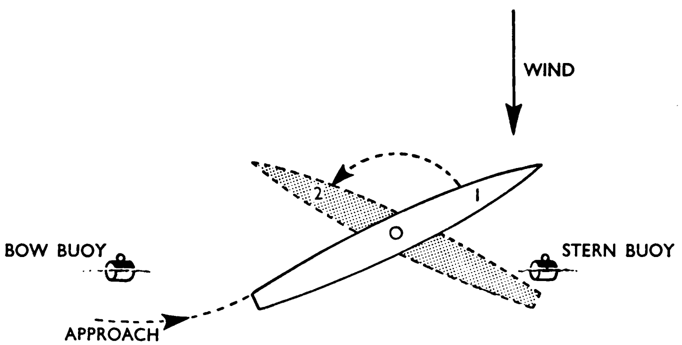

FIG. 13–13. Approach too close to stern buoy before turning at rest to secure between two buoys

A worse situation is likely to arise if the ship is placed initially too near the stern buoy. Fig. 13–13 shows a similar situation to that in fig. 13–12, but with the ship in the first place too close to the stern buoy. From position 2 it may well be more difficult to get ahead and complete the turn without fouling the stern buoy, which in any case is difficult to see from the bridge. Again, if the wind had been from the opposite direction it would have been trickier for the ship to extricate herself astern from position 2.

Turning a small ship between two buoys

A single-screw ship should normally be secured between two buoys with the help of tugs, but a reasonably handy single-screw ship, or a small ship of any kind, may be turned and secured between two buoys by the following method

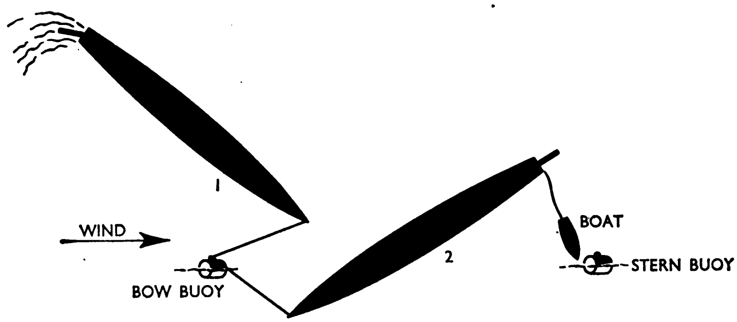

FIG. 13–14. Securing a small ship between two buoys by turning on the head buoy

in fair weather: If there is no wind or stream, the ship uses the bow buoy to turn on. The ship should approach and stop so that the stem lies about one-third of the length of the berth from the bow buoy (fig. 13–14, position 1). Having secured the picking-up rope to the bow buoy, the ship is turned by moving the engines slow ahead with full rudder, and at the same time the picking-up rope is hove in. Having turned about as far as position 2, the stern rope can be made fast and then both head and stern ropes hove in. This method can be used also if it is necessary to approach before the wind.

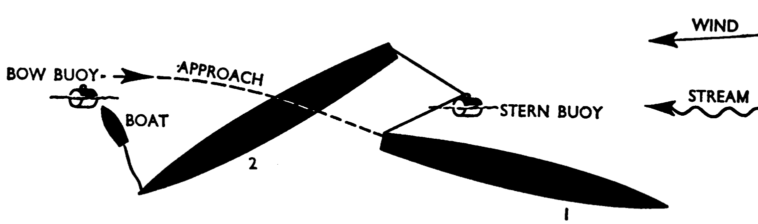

FIG. 13–15. Securing a small ship between two buoys by turning on the stern buoy

If the wind or stream, or both, are setting out of the harbour the ship should approach as shown and stop with the stern reasonably close to the stern buoy, keeping the wind or stream on the bow (fig. 13–15, position 1). The picking-up rope is secured aft to the stern buoy and then the wind and stream will swing the ship round stern-to-wind, while a boat is being sent away with the picking-up rope for the bow buoy (fig. 13–15, position 2).

Slipping from head-and-stern buoys

The forward and after slipropes can be let go together and the ship be turned by her engines to get the bow and stern clear; with a single-screw ship it may be necessary to use a tug if the space is very limited.

In a wind, if it is directly along the line of the buoys, the lee buoy should be slipped first. When the weather sliprope is surged and let go the buoy will spring clear and the ship will tend to swing beam-on to the wind. She can then go either ahead or astern, as necessary, to clear the berth.

If you want to leave by going either directly ahead or directly astern when the wind is on one side or the other, both slipropes should be surged until the ship lies well to leeward of the berth; both slipropes should then be slipped together and the ship moved off in the required direction. If it is necessary to leave the berth at an angle to the line of the buoys, the ship can be cast in the required direction by slipping one buoy first and allowing the wind to blow her round before slipping the other.

USE OF BERTHING HAWSERS

Intelligent handling of berthing hawsers can add greatly to the ease and speed with which a ship is berthed alongside, and the effect of heaving in any particular hawser under any given circumstances must be known. The standard nomenclature of berthing hawsers used in the Royal Navy is given in Volume I, together with other information on how to handle hawsers.

Effect of hawsers on movement of ship

It is assumed in the first place that the ship is stopped and lying square with the jetty. If a fore breastrope is then made fast and hove in, the bows will obviously be moved in towards the jetty; but, because the ship will also turn about her pivoting point, her stern will move away from the jetty at the same time. This movement of the stern will not be as great as that of the bows, because the pivoting point is not rigidly held, and so the ship will also move bodily towards the jetty. If, on the other hand, an after breastrope has also been made fast and held taut, the ship would have pivoted about her stern as the fore breastrope was hove in, and she would have been swung in towards the jetty by the bows. If both fore and after breastropes are hove in together, the ship will be breasted in squarely with the jetty. If either of these hawsers is led ahead or astern it will act as a spring, and as it is hove in the ship will be moved ahead or astern at the same time as she is moved towards the jetty.

It is now assumed that the ship has a certain amount of headway when the fore breastrope is made fast. As the ship moves ahead this hawser will grow aft and, as it tautens, her head will be bowsed in towards the jetty. The momentum of the ship acting through her centre of gravity will increase this swing, because the ship will then pivot about her bows and her stern will swing out. If, instead of the fore breastrope, an after breastrope has been made fast the result would have been very different. The pivoting of the ship would then have been well abaft her centre of gravity, and her forward momentum, acting through her centre of gravity, combined with the pull of the hawser on her quarter, would have resulted in the ship being moved in bodily towards the jetty and very nearly parallel with it.

Summarised, the difference is that with a ship moving ahead a fore headspring bowses the bows in sharply and swings the stern out, whereas an after headspring

will scarcely turn the ship; in both cases, however, the ship is moved bodily in towards the jetty. With the ship moving astern, these effects are, of course, reversed.

Should the spring be led from the ship abreast her centre of gravity, she will move in bodily without being cast in either direction, and her alignment with the jetty can then be altered by using rudder.

BERTHING ALONGSIDE A JETTY

Multiple-screw ship berthing alongside in calm weather

In calm weather with no stream a multiple-screw ship should be steered towards the middle of the berth in the final approach to an alongside berth, at

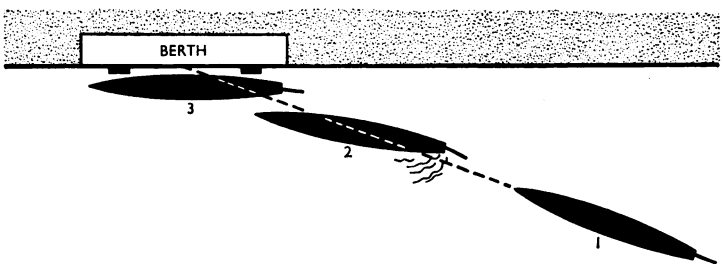

FIG. 13–16. Approach alongside in a multiple-screw ship in calm weather. 1. Engines stopped, wheel amidships, heading for centre of berth. 2. Offshore engines slow astern, wheel as required. 3. Ship stopped about 15 ft from fenders

an angle of between 15° and 20° to the line of the berth. The offshore screws should be put to slow or half astern so as to bring up the ship parallel to the berth, the wheel being used as necessary (fig. 13–16). If possible, the inshore screws should not be used to check the way of the ship, because their wash will tend at first to throw the stern out and then, as a mass of water is propelled forward between the ship and jetty, they will cause the whole ship to be moved bodily outward.

Adequate catamarans must be provided for ships whose propellers project beyond the maximum beam of the ship. Suitable types of catamaran and fendering are described in Volume II. Even with 10-ft catamarans amidships, propellers projecting 2 ft 6 in. will touch the wall if the ship lies stern-in at an angle of only about 5°. In such ships the greatest care must be taken that the after part does not touch first.

Multiple-screw ship with wind blowing on

If the wind is blowing on to the berth the approach should be made at the same angle as in calm weather but from a point further out, so that the ship is heading for the far end of the berth, or for a point even further up the jetty (fig. 13–17). In a ship greater than, say, 5,000 tons displacement the aim should be to stop the ship, preferably by going astern on the offshore engines only,

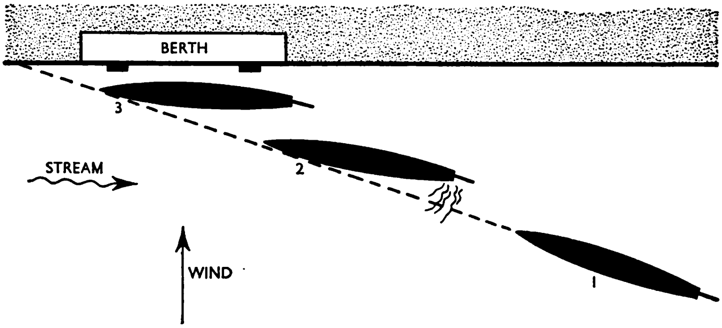

FIG. 13–17. Approach alongside in a multiple-screw ship upstream with wind blowing on. 1. Engines stopped, heading for far end of berth. 2. Offshore engines slow astern. 3. Ship about 30 ft from fenders

parallel to the berth and about 30 ft off the fenders, if the wind is blowing strongly onshore. If she is brought up much further out she will gather excessive leeway before touching. The effect of going astern on the inshore screws may be used to advantage if the stern develops too fast a swing in, or if the wind is setting the ship too rapidly towards the quay. In assessing this effect, the nature of the jetty (i.e. whether solid or built on piles) and of the contours of the sea-bed in the vicinity must be considered in advance.

In a stiff onshore wind (or stream) it may be necessary to use an anchor during the approach, letting it go when stopped some distance off the jetty and parallel to the berth (see also p. 309).

A ship of shallow draught with high forecastle and superstructure forward tends to pay off the wind rapidly as soon as way is lost. In such a ship there is a danger that the bows may be blown down heavily on to the jetty, if the anchor has not been used initially. To avoid this, one must try to keep the bows swinging slowly outwards during the whole manœuvre, and a stream from ahead combined with the use of the wheel will help.

However, if the bows take charge and start to swing rapidly towards the quay there are three possible remedies. One is go astern on the inner screw, as described above; but some time will elapse before the pressure of water between ship and quay has built up, and meanwhile the swing will be accentuated. A second is to give a burst of ahead power with the wheel hard over away from the berth. This will probably check the swing and will be an effective remedy if there is still room to gain the inevitable headway. Finally, one may drop an anchor. The inshore anchor will probably give the more immediate check to the swing, but may be difficult to weigh on leaving the berth; hence it is more usual to let go the offshore anchor. To put astern power on the offshore screw is not likely to help, partly because it will cause more water pressure towards the berth, and partly because the stern tends to seek the wind once sternway is gathered.

Multiple-screw ship with wind blowing off

If the wind is blowing off the berth it is essential to keep the bows well up to the jetty until a hawser has been passed. Once the stem has drifted outside the throw of a heaving line the situation can seldom be recovered except by a tug.

It is therefore wise to approach at a rather greater angle than in calm weather, to head the ship initially towards the nearer end of the berth and to get the bow wire passed at the first opportunity.

If the wind is blowing off the jetty, but more nearly from astern, the approach at a broad angle may place the ship in an awkward predicament after the bow wire has been secured. The wind now presses the entire hull outwards while the bow is held, and it may be very difficult to work the stern in (fig. 13–18, position 1). It is therefore better with the wind aft to approach at a fairly shallow angle (position 2).

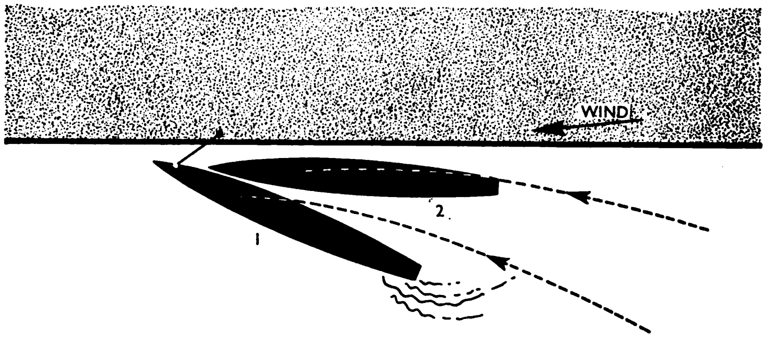

FIG. 13–18. With wind along the jetty, the broad approach (1) may make it more difficult to swing the stern in than a finer approach (2)

Effects of current or tidal stream

If the stream is running parallel (or nearly so) to the jetty, either from ahead or astern, and provided the wind is not too strong, the shiphandler can use the stream to control the lateral movement of the ship. First, he should stop the ship off the berth and heading directly into the line of the stream. If the stream is from ahead he can now use the wheel so as to bring the pressure of the stream on to the desired bow and so move the ship laterally either to starboard or port as required, using slight ahead or astern revolutions as necessary to keep the ship stationary relative to the berth. If the stream is from astern the same principle can be applied, the stern being canted so as to bring the stream on to the appropriate quarter.

Not infrequently it is found that berths have strong eddies running in the opposite direction to the main stream, and at pile jetties there are sometimes eddies running at an angle to the jetties. The presence of such eddies can usually be discovered in advance by studying the Sailing Directions or by making local inquiries and the plan for approaching the berth modified accordingly.

Checking the way

It is perhaps even more important in approaching alongside berths than in coming to an anchor or a buoy to make a plan in advance to show when and where to reduce speed and stop engines, in order to avoid making the final approach with too much headway. This applies particularly if the wind or stream are from astern.

If the wind is blowing the ship down laterally on to the berth it is essential to check all head- or sternway before she touches. The damage done by scraping along a wall or another ship will almost certainly be far more extensive than that caused by a sideways bump, whose worst effects can usually be prevented by fenders.

Berthing alongside in a single-screw ship

The foregoing remarks apply generally also to the berthing alongside of a single-screw ship, but one must consider the very marked sideways force of the propeller that is found in a single-screw ship. Remember that when the engine is reversed to take the way off the ship the sideways force from the astern-turning right-handed propeller will swing the stern to port and the bow to starboard; but also that when going slow ahead the propeller slipstream will impinge directly on to the rudder and so have an immediate effect. Thus when going alongside port-side-to in fairly calm weather the approach should be made at an angle of about 15° to 20° with the jetty, heading for a point a little ahead of the centre of the berth. When the engine is put astern, the stern will swing in towards, and the bows away from, the jetty. The rate of swing can be checked if necessary by the headrope.

When going alongside starboard-side-to in a single-screw ship the angle of approach should be rather finer, say from 10° to 15° with the jetty, and the ship headed for the centre of the berth. As her bows approach the jetty the wheel should be put over to port and the engine be given a kick ahead to swing her bows away from, and her stern towards, the jetty. Just before the ship is parallel to the jetty the engine should be put astern and the sideways force from the propeller should then counter the ship's swing so that she is stopped parallel with the jetty abreast her berth. As before, if the rate of swing is too great it can be checked by a headrope. Dredging the anchor (page 294) may be a help if there is a strong off-shore wind.

Use of spring to bowse a ship in

If there are ships berthed ahead and astern of the berth it may sometimes pay to get the bows in first, secure a headspring in the manner shown in fig. 13–19 and then swing the stern in by going ahead on the spring with the wheel over away from the jetty, surging the spring if need be.

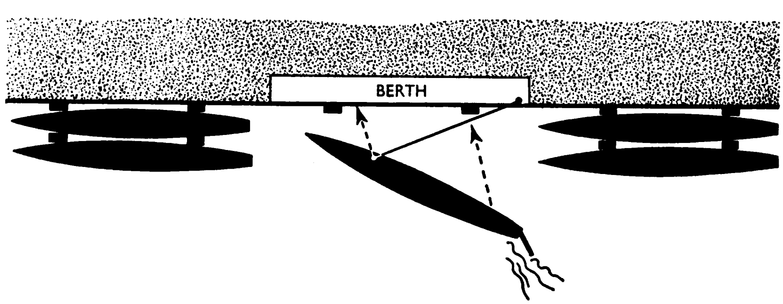

FIG. 13–19. Bowsing in by going ahead on a headspring

LEAVING AN ALONGSIDE BERTH

Use of spring to swing the stern out

When leaving an alongside berth unaided by tugs it is usually preferable to leave stern first, after swinging the stern clear by going ahead against a fore headspring. It is helpful to investigate the mechanics of the manœuvre so that one can be sure before starting that the spring is rove in the most advantageous way.

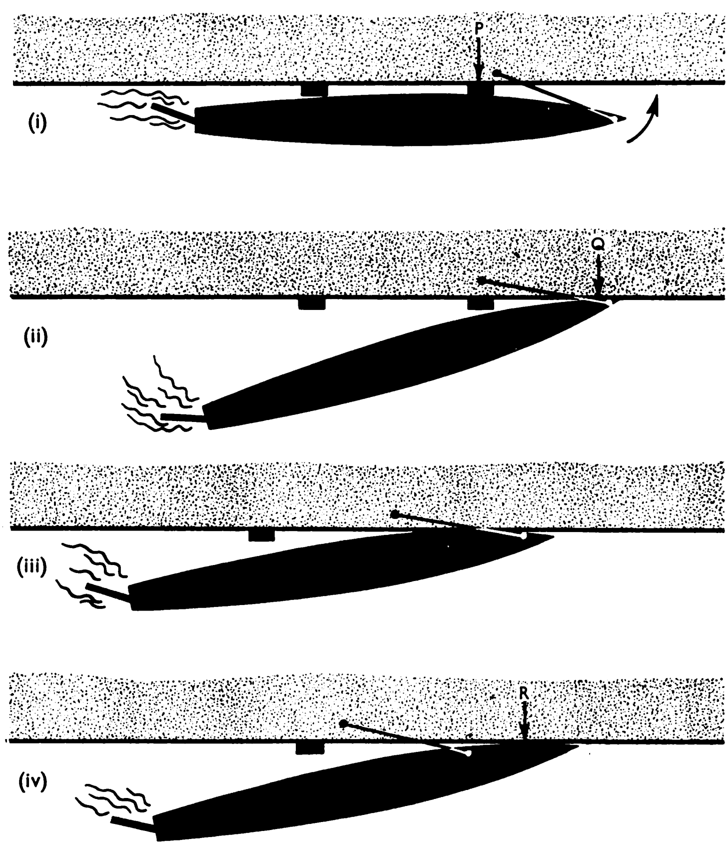

FIG. 13–20. (i) Correct position for fender and spring giving turning moment. (ii) Ship now pivots on stem; no turning moment from spring. (iii) Fender too far aft; turning moment from spring soon lost. (iv) Spring too far aft; hinders turn as soon as bows touch jetty

In fig. 13–20 (i) the line of the entire spring is forward of the point at which the ship bears initially on the catamaran or fender (*P*). As soon as the engine is put ahead there is a good turning moment tending to swing the stern out, and this situation continues until the stem bears against the jetty (*Q* in fig. 13–20 (ii)). After this the engine and rudder will be the sole agents available for swinging the ship further out, if this is required. If the catamaran or fender against which the ship is to bear is placed further aft, as is shown in (iii), the turning moment

arising from the spring will be lost much earlier. So it is clearly an advantage to reeve the spring from well forward in the bows and to place the fender up forward, so long as it is not forward of the point on the jetty where the spring is secured. If the fender is forward of this point, or if the spring is rove further aft, one is liable to be faced with the situation shown in (iv). Here the spring actually tends to stop the swing as soon as the bows have come up against the jetty, as at *R*.

A good supply of fenders must be provided to take the push where the bows rest on the jetty, and because of the flare it is easier to tend these fenders on the quay. Even so, the shiphandler must proceed with the utmost care to avoid damaging the plating on the inner bow. If the catamaran and spring have been correctly placed it should in many cases be possible to obtain sufficient outward swing without the stem having to touch at all. This is particularly so in a multiple-screw ship. The initial movement against the spring should be made by going slow ahead with the offshore engines, with the wheel over towards the wall. If the inshore engines are put to slow astern as soon as the stern is clear, they will assist the swing by forcing a stream of water ahead between the wall and the hull, tending to move the entire ship outwards. If the astern revolutions on the inshore engines are continued, however, the stream of water working forward will eventually push the bows out and cause the stern to swing in again as stern way is gathered. This possibility must be foreseen when deciding how far out to swing the stern initially.

Effects of wind and stream on leaving an alongside berth

If a stream is setting along the jetty from aft it will force the stern out as soon as the after wires are let go, and it may not be necessary to go ahead against a headspring.

If the wind is blowing onshore, although it may be possible to swing the stern out by the use of the engines, wheel and headspring, there is a danger that when making a stern board out of the berth the bows will be scraped along the wall. If the wind is of any strength it is essential to use tugs, or alternatively to warp the ship out if this is practicable. The problems of getting away from a quay in strong onshore winds are discussed further in Chapter 15.

The difficulty of getting the bows clear also presents itself if the stern is sprung out when the stream is running from ahead. An alternative plan is to go astern on a backspring rove well aft and swing the bows out, but this procedure involves the risk of getting a propeller foul of the jetty and is not usually advisable in multiple-screw ships, particularly those with proud propellers.

An offshore wind is obviously a great boon. By letting go the forward or after wires first, either the bows or stern can be allowed to swing out. Alternatively, if all hawsers are let go together the ship will drift bodily away from the quay. But if the ship has some high mass of superstructure either forward or aft, the effect of the wind on this must be anticipated. For example, in a ship having much windage forward it is best to let go the after wires first and hold on to the headrope until the stern is well out.

Single-screw ship leaving an alongside berth

As always, the sideways force of the propeller must be taken into account. When leaving a starboard-side-to berth astern, the stern need not be sprung out

too far, because it will swing rapidly away from the jetty as soon as the engine is put astern. Do not allow the bows to scrape along the berth, and be prepared to use starboard wheel when going astern. Adequate fendering must be provided. When swinging the stern out from a port-side-to berth the swing must be continued to a much greater angle to allow for the fact that when going astern the stern will swing rapidly back towards the jetty.

If there is a wind, or tidal stream or river current, from ahead, it is usually perfectly practicable in a single-screw ship to go astern on a backspring in order to swing the bows out. There is usually little danger of fouling the propeller, but adequate fendering must be placed to take the push of the ship's quarter on the wall. The mechanics of the spring must be arranged on similar lines to those required for a headspring, as already described.

BERTHING ALONGSIDE ANOTHER SHIP

Going alongside a ship at anchor

Going alongside a ship at anchor in calm weather is very similar to going alongside a jetty, except that the anchored ship is free to swing and will pivot round her stem, and the water pressure from your bows as you close the anchored ship will tend to swing her stern away if the approach is made too fast and at too fine an angle.

The approach in a twin-screw ship should therefore be made at an angle of about 15° with the other ship, at slow speed and with the ship headed for the bows of the other ship. The approaching ship is then stopped by reversing her

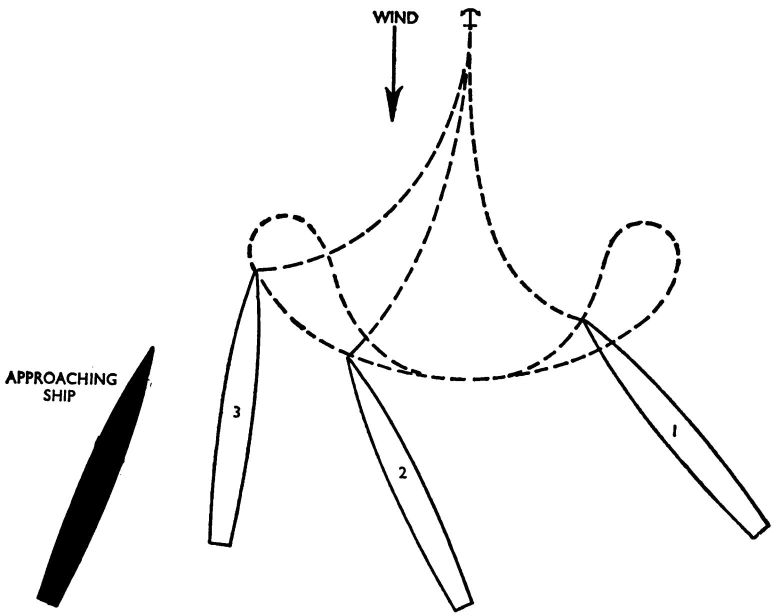

FIG. 13–21. Going alongside a ship yawing at anchor

outer engine, and the berthing hawsers, particularly the after ones, are passed and secured as quickly as possible. When alongside each other, the ships should be kept apart by catamarans (usually provided by the anchored ship), and each should be well fendered at the break of the forecastle or just before amidships where first contact between the two ships is most likely to occur.

In a wind, particularly one of any strength, the anchored ship will probably be yawing, which will make the manœuvre more difficult. The stem of a ship yawing at anchor traces a path like a figure of eight, as shown in fig. 13–21. As the ship reaches the limit of her yaw to one side, in addition to her broadside movement she will come up into the wind and surge ahead. She will then drop back as she yaws to the other side. Before going alongside a ship which is yawing she should be watched carefully to determine the extent of her yaw. The approaching ship should then be stopped just outside the limit of the other ship's yaw to one side, heading a little off the wind and pointing towards the anchored ship as in fig. 13–21. Then, as the anchored ship again approaches the limit of her yaw to that side, the approaching ship can be edged in towards her and placed alongside her as she begins to yaw in the opposite direction. The manœuvre requires good judgment and smart handling of the berthing hawsers. When there is risk of damage to either ship, the yawing ship should let go a second anchor.

Slipping from alongside another ship

When slipping from alongside a ship at anchor or secured to a buoy in calm weather it is useless to try to cast the bows or stern out on a spring, because both ships will pivot together round the cable of the anchored ship. If all the hawsers are let go the ships will soon drift apart, and in a small ship this drift can be helped by bearing off the other ship.

In a wind it is best to let go the forward hawsers and hold on to the after ones until the bows of the two ships have swung sufficiently far apart, and then let go the after hawsers and go ahead when the sterns of the two ships are clear. The inner wing propellers of the two ships must not be allowed to foul each other.

USE OF AN ANCHOR AT AN ALONGSIDE BERTH

Letting go an anchor before going alongside

In some harbours it may be necessary to let go an anchor before going alongside, so that when the ship subsequently casts off, her bows can be hauled clear of the berth by her cable. She then weighs her anchor and goes ahead into the fairway. The anchor should be let go in such a position that, when the ship is secured alongside, the cable grows abeam and with sufficient scope to ensure the anchor holding when the bows of the ship are subsequently hauled off; the shallower the water the closer to the jetty can the anchor be let go. If for some reason it is only possible to allow a very short scope of cable it is best to use the inshore anchor so that the cable leads under the ship's bottom to the anchor; there will then be a better chance of the anchor holding as the bows are hauled off. In H.M. ships the offshore anchor is often preferred, in order to avoid damage to the hull plating or underwater fittings. If, after clearing the berth,

the ship has to turn by steaming round her anchor, it should be let go some distance away from the jetty.

In calm weather the ship approaches at right angles to the jetty and pointing to the head of her berth; and as the anchor is let go at the required distance from the jetty, the rudder is put over to swing the bows in the required direction. As the way of the ship is reduced the cable is braked to assist the swing of the bows, and a headrope is passed ashore and used to prevent the bows swinging out too far. The ship is eventually stopped a little more than half a ship's length ahead of her berth, when a stern rope is passed ashore and the ship backed stern first into her berth. In a single-screw ship allowance must be made for the sideways force of the propeller as the ship is backed into her berth: for example, if she is to lie starboard side to, her bows should be inclined away from the jetty when the engine is put astern. The use of an anchor may also be dictated by a stiff onshore wind (or stream) when berthing (see p. 303).

Slipping from alongside with an anchor down

When slipping from alongside with an anchor down the stern must be cast out on a spring or hauled out by a tug before the bows are hove out by the cable, otherwise the stern will foul the jetty and possibly damage the rudder or propeller. As the bows are hove out the stern must be held in position, either by the tug or by working the engines against the cable, or the stern may swing in again and foul the jetty. The heaving-out of the bows should be controlled by a fore breastrope to prevent the ship from overriding her anchor.

In calm weather the help of a tug is not essential. In a single-screw ship, lying port side to, the stern is first cast well out on a spring, and then as the cable is hove in the engine is put slow ahead with the rudder to port. The ship's bows will be held by her cable while the sideways force of the ahead-turning propeller will tend to swing her stern to starboard and so move the ship bodily away from the jetty. In a single-screw ship lying starboard side to, her engine is put slow astern after her stern has been cast well out on a spring, and the cable is then hove in. The sideways force of the astern-turning propeller will tend to kick the stern of the ship to port and so prevent it from swinging towards the jetty as the bows are hove off by the cable. Take care while manœuvring that the ship does not gather any appreciable way and so strain or part her cable.

In a twin-screw ship the inshore engine is put slow astern, and the offshore engine slow ahead, while the cable is hove in. The sideways force of the propellers working against the pull of the cable will result in the ship moving bodily away from the jetty.

In an onshore wind the help of a tug to haul the stern out, and to keep it from swinging in while the cable is hove in, is essential unless the wind is light and the ship particularly manœuvrable.

STERN-TO BERTHS

In some harbours where there is insufficient room to berth many ships alongside, some ships are obliged to berth at right angles to a jetty, with their sterns secured to it by hawsers and with their anchors laid out ahead. It is preferable to use both anchors rather than one, and to span the cables at an angle of about 20°,

so as to make the ship more secure in a wind. It is obvious, however, that the berth will not be a safe one if a gale blows from abeam. If such weather is forecast it may be advisable to leave the berth and put to sea or seek a sheltered anchor berth.

Approach to a stern-to berth

In a multiple-screw ship in calm weather the approach is made parallel to the jetty towards the position where the first anchor is to be let go. A good way of establishing this position is by bearing and distance of the bridge from the stern

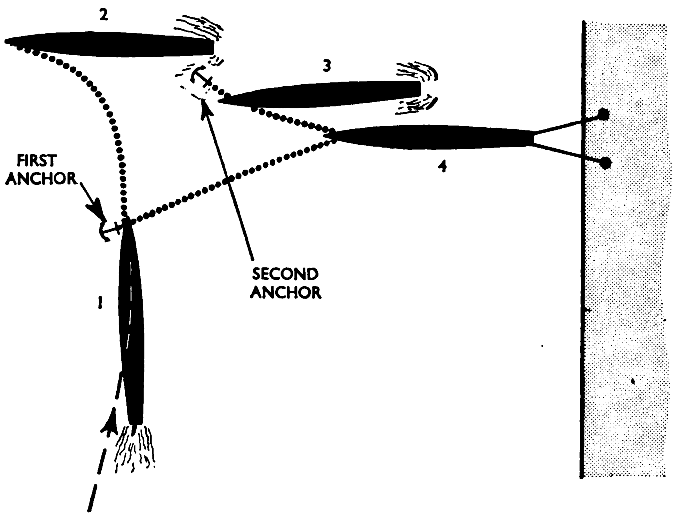

FIG. 13–22. Approach to a stern-to berth in calm weather

bollard of the berth on the quay. Having let go the first anchor (fig. 13–22, position 1), the ship is turned by the engines nearly at rest, but with a little headway, until she is lying parallel to the berth but slightly beyond it (position 2). She then goes astern into the berth, letting go the second anchor somewhat inshore of the first. Cables are veered, and the stern hawsers are passed as soon as the stern is close enough to the jetty. Note that if the stern way is checked by

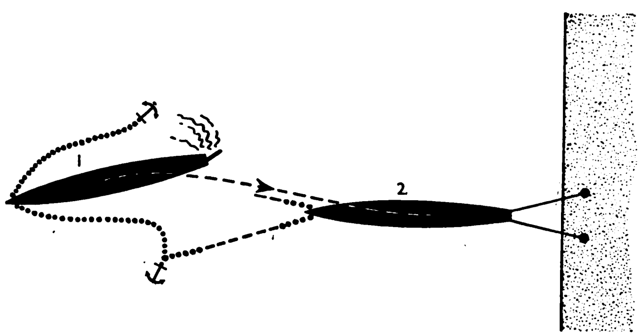

FIG. 13–23. Going astern into a stern-to berth in a single-screw ship

braking the cables their weight will tend to spring the ship forward and they may have to be veered again roundly to prevent this, or the engines kept moving very slowly astern until the stern hawsers are secured.

In a single-screw ship, having let go the first anchor, go ahead letting the cable run until she reaches the position for letting go the second. The second anchor is now let go and its cable allowed to run, while the cable of the first anchor is held and the ship turned on it. The sideways force of the propeller while the ship gathers way astern into the berth must be allowed for in the amount of the initial turn; before going astern the ship must be heading to port of the line of the berth (fig. 13–23).

Effect of wind in the approach to a stern-to berth

A wind blowing directly on to the jetty obviously makes the whole manœuvre easier, because it assists the initial turn and then helps the ship astern into the berth. However, if the wind is blowing more or less parallel to the jetty it can be put to good use if the approach is made downwind. The ship will turn readily on the first anchor provided she is given a swing at the start to make sure the wind blows on to the offshore quarter (fig. 13–24). The movement astern into the berth is easily controlled because if sternway is made the stern will work up into the wind, but if the way is checked the stern will drift down towards the line of the berth. She should finally be brought to rest to windward of the berth to allow for drift while stern hawsers are being secured.

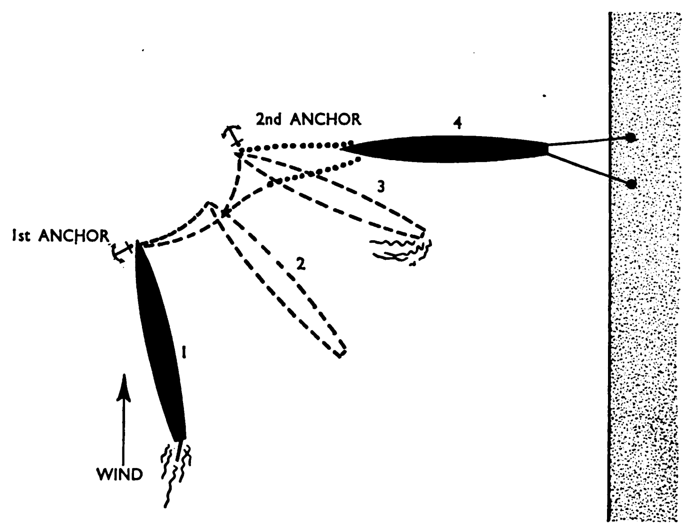

FIG. 13–24. Approach to a stern-to berth downwind

If the wind is parallel to the jetty but from ahead, or if there is not much room round the berth because of other ships already moored either side of it, the approach can be made as in fig. 13–25 in a multiple-screw ship. The ship is first turned at rest so as to finish up broadside to the wind in a position to windward of, and offshore of, the intended positions of the anchors. She then goes astern, letting go first the windward and then the leeward anchor. It is not possible to

obtain much span between the anchors, but the movement astern should be easy to control for the reasons already given.

A wind blowing directly off the jetty is a hindrance, but in a reasonably manœuvrable multiple-screw ship the berthing should be feasible without assistance. In a single-screw ship, however, it is difficult to turn stern to wind with anchors down, and even more so to back into the berth under control; the help of a tug is therefore strongly recommended.

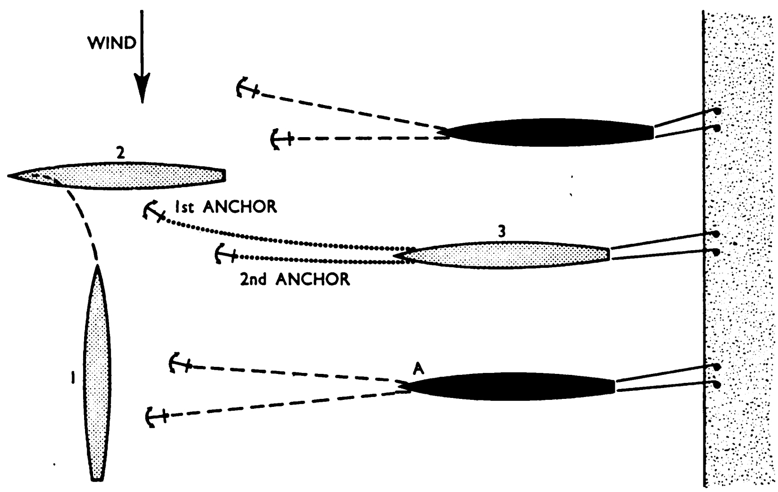

FIG. 13–25. Berthing stern-to in a tier

Leaving a stern-to berth

When slipping from a stern-to berth it is not advisable to keep a stern rope rove while the cables are hove in, because it would have little effect in checking any swing of the stern and it might foul the propeller or hamper the use of the engines when they are needed.

The positions of the anchors should be plotted and considered in relation to which way the ship will swing as she leaves the berth. For example, in fig. 13–25 the centre ship will swing to starboard because of the wind as soon as the stern ropes are slipped. If she attempts to weigh the leeward anchor her stern will foul the adjacent ship at A. She must obviously use the engines to move ahead until her stern can swing clear, thus overriding the port anchor before it is weighed. But if she moves well clear ahead and swings head to wind before weighing there is considerable danger of a foul anchor, because in this case the starboard cable will have been dragged across the port (fig. 13–26). Her best method in these circumstances would be to move well clear ahead of the berth with the assistance of the engines until over the position of the starboard (windward) anchor and then weigh it, keeping the ship as nearly as possible on the heading of the berth by using the engines while this is done. She may then be allowed to swing head to wind and to drop astern over the port anchor and weigh it. Clearly it is an advantage to drop one of the anchors in the first place sufficiently far out to enable the stern to be hauled clear of adjacent ships when unberthing.

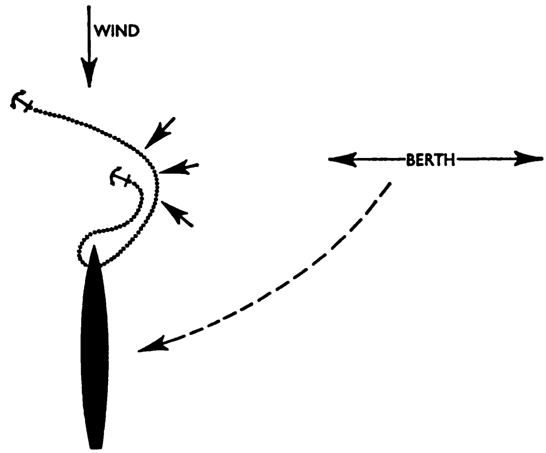

FIG. 13–26. Danger of foul anchor when leaving stern-to berth in a beam wind

EMPLOYMENT OF HARBOUR PILOTS

The relations between Captain and pilot, and the ultimate responsibility of the Captain for the safety of his ship, are laid down in *Queen's Regulations & Admiralty Instructions*. The pilot should be regarded as the expert on local conditions and in certain circumstances the Captain may have to rely entirely on his knowledge, but this does not necessarily mean that the actual handling of the ship should be undertaken by the pilot. While it is normally desirable for the Captain to handle the ship, with the pilot offering the necessary information, there may be occasions—where tugs are employed, or expert local knowledge is necessary—when it will be preferable for the pilot to order the precise movements of the engines and rudder, in order to avoid the controversial procedure of dual control. It is advisable to pass the pilot's orders via the Officer of the Watch, particularly if the pilot's knowledge of English is not fluent. Nevertheless, whatever procedure is adopted, the Captain's responsibility remains.

The procedure in British naval ports is also laid down in *Q.R. & A.I.*

There are occasions when the employment of a commercial pilot is compulsory. In foreign ports, particularly in traversing rivers or inland waterways where local traffic regulations or speed limits may be in force, it is advisable to use a pilot on the first occasion of entry and leaving, at the least. On other occasions the services of a pilot to control tugs may be necessary because of his knowledge of the language or of the signals to be used. However, as he acquires experience of a port a Captain should dispense with the services of local pilots as soon as practicable. It is essential to develop pilotage skill in Her Majesty's ships so that they will be able to cope with intricate pilotage tasks in active operations or war, when no local assistance may be available.

MANŒUVRING WITH THE HELP OF TUGS

While it is good training to manœuvre without tugs, especially in ships with reserves of power and excellent handling qualities, there are occasions when the

use of tugs is necessary, even in quite small ships. For example, the finest ship-handler in the world could not hold his ship stopped between buoys in a strong beam wind without external aid. If conditions are doubtful it is better seamanship to employ tugs at the outset rather than to call them in to extricate the ship from a difficult position at a late stage, when it may be much more difficult to get the tug secured and exerting her force in time to save the situation. It is unwise not to use tugs on occasions, and it should not become a matter of pride to refuse the help of tugs in all circumstances. Quite often the Captain need not use a pilot to control the tugs, but may do so himself; but if he does he must use either the local code of whistle or flag signals, or voice radio if available, and must avoid shouting orders or gesticulating. The minimum instructions should be passed to tugs, and it is often better to tell them what job to do (e.g. 'hold my bows up to starboard') rather than how to do it. Tugmasters are experts at their work and can be expected to know the quickest and most efficient way of applying the force required. It is an advantage to discuss the manœuvre in advance with the tugmasters, if possible.

Types of tug and their capabilities

Single-screw, medium-powered tugs are the best to use with a rope from their towing hook. They steer well at slow speed, and are thus suitable for towing ahead; and they can also maintain their position easily and without loss of power when pushing.

High-powered twin-screw tugs have considerably less control when towing ahead, but can maintain their position well when pushing or when pulling astern with a rope out over the bow.

Paddle tugs are handy for pushing work, but are not handy for towing ahead, the towing-hook being placed abaft the pivoting point because of the siting of engines and paddle-boxes. Their forte is towing alongside, where they can exert a large turning moment when it is needed, and also can develop high astern power. The protrusion of the paddle-boxes enables them to fit in alongside ships with overhang, such as aircraft carriers, but precludes their use alongside submarines.

Girding

Ships should avoid gathering head- or sternway when a tug's hawser is growing at a broad angle to the ship's fore-and-aft line, e.g. when hauling off a wharf.

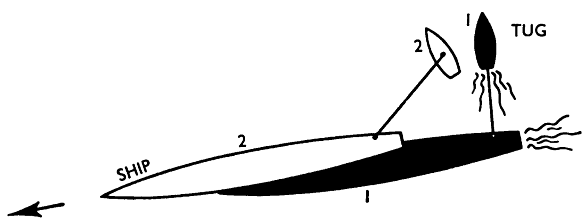

FIG. 13–27. Girding. 1. Ship goes ahead while stern is being hauled out. 2. Tug girded and in danger of being capsized

Lack of judgment in such circumstances may manœuvre a tug into a helpless position, possibly capsizing her (see fig. 13–27).

Modern tugs have great engine power in relation to their size, and the strength of their towing hawsers is in proportion to their engine power. Consequently if a tug is *girded*—that is to say, pulled laterally through the water, with the towing hawser growing out on her beam—it cannot be guaranteed that the hawser will part before she is capsized; moreover, in these circumstances there is a possibility of the slipping arrangements in the tug failing to function. Slipping arrangements must also be provided in the ship being towed, but it should be remembered that when a hawser under strain is slipped from a high-freeboard ship it is liable to endanger the crew of the tug.

Turning in a confined space with the help of tugs

If a multiple-screw ship has power on her main engines she should not secure tugs alongside if it can be avoided. The ship's own engines provide a considerable turning moment, and the presence of the tug alongside will probably not expedite a turn and may cause damage to the ship's side if there is a swell. A better method of using tugs to help a turn is to use a small tug ahead pulling, and to secure a large tug by a hawser close in to the quarter in the manner shown in fig. 13–28. This large tug not only pushes the stern round but holds it in position when required, e.g. to secure to a buoy. She can either push by going ahead or pull by going astern on the hawser, as need be. A third tug may stand by to push or pull from the beam as required.

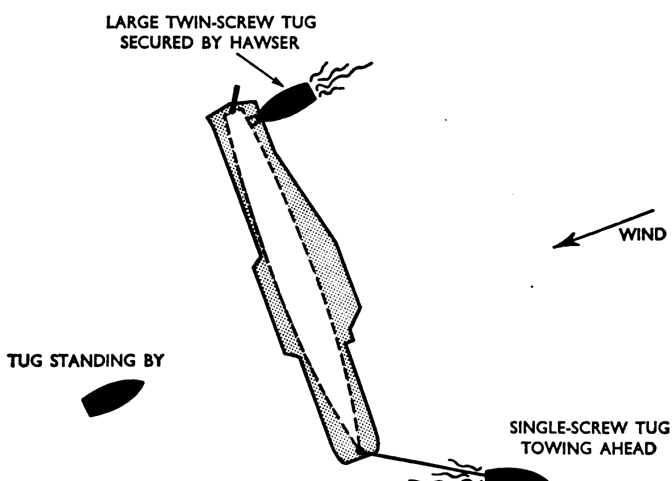

FIG. 13–28. Turning an aircraft carrier at rest with the aid of tugs

Heavy ships such as aircraft carriers should normally use this method when turning at rest in a confined space. Smaller ships may prefer to modify the method, depending on the weather and the power they have available. A cruiser, for example, may not secure a tug at all but merely have one standing by fore and aft to push if required. If, however, this plan is adopted it must be accepted that a tug may not be able to maintain correct position all the time, ready to push the instant she is required.

Securing alongside or to buoys with the help of tugs

The most usual occasion when tugs are needed in berthing alongside is when there is an offshore wind, and the obvious way to use the tugs is to have them push from the leeward side. This applies also to berthing between two buoys in a beam wind. If two tugs are available one is placed forward and one aft. If only one is available it may be difficult to judge where is the best place for her to push, but it will obviously be somewhere near the centre of gravity.

When employing tugs to push, the thinness of the plating used in parts of the structure of some modern warships should be borne in mind. It should be realised also that it is very difficult for the tug to maintain position if the ship acquires any appreciable head- or sternway, or if there is a strong stream running.

Slipping from alongside with the help of tugs

If two tugs are available one should secure to the ship's bows and the other to her stern, each by a short towrope led from the towing hook, and then both tow the ship off the jetty broadside on. When well clear of the jetty the tugs can be slipped, if no longer required, but they are often kept in attendance to assist the ship out of harbour.

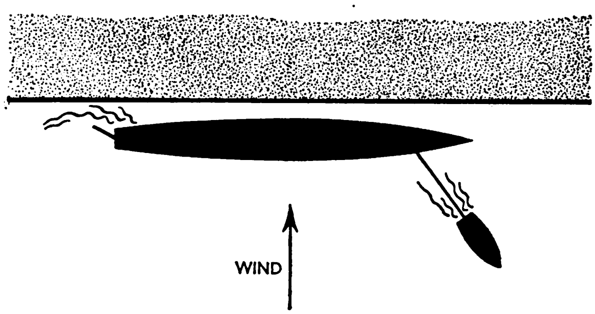

FIG. 13–29. Using a tug to assist in leaving an alongside berth in an onshore wind

If only one tug is available to get a ship away from a jetty in an onshore wind, she should tow outwards from a point fairly well forward, between the stem and amidships. As the tug begins to haul off, the ship should work her engines and wheel as necessary to swing the stern out (fig. 13–29). The ship then moves bodily outwards. In a single-screw ship some headway will be gained by the need to go ahead with the wheel hard over towards the jetty; the direction of tow of the tug should therefore be forward of the beam to avoid her being girded.

Moving about in harbour with the help of tugs

Having got away from a jetty with the aid of a tug hauling off forward, it is necessary sometimes to continue using this tug to help tow the ship round some sharp bend. The ship should not go ahead until the tug has moved round ahead of her, and it may be necessary also to move the tug's wire to the ship's stem before starting. A tug secured from her bows to the ship's stern is able to work her engines so as to assist the action of the ship's rudder and engines when

negotiating sharp bends, a paddle tug being particularly suited to this function.

When a tug is towing ahead the ship's speed must not be allowed to rise above a point about 3 knots below the tug's maximum speed, because when the tug is required to slip the tow she will have to reduce speed, and having done so the drag of the towing hawser will reduce her speed still further. In practice a heavy ship can usually proceed at about 7 knots with a Dockyard screw tug towing ahead. During a turn, the reduction of ship's speed allows the tug to recover position ahead, but the tug must work over to the inner bow of the ship before the turn is started. If she does not do so, she will not only hinder the turn but also run the risk of being girded.

PASSING THROUGH A NARROW ENTRANCE

The difficulties in passing through a narrow entrance either when entering or leaving harbour arise from the desirability of approaching on a steady course at right-angles to the line joining the two jetties, or from the presence of a cross wind or stream. If there is no room to approach at right-angles the use of tugs or warps is essential. For example, in leaving the berth shown in fig. 13–30 a good method would be to secure the warp in the manner shown, and then to go ahead on it with full port wheel in order to bring the ship round to head through the entrance. As soon as she has reached position 3 the warp is cast off and the ship goes ahead.

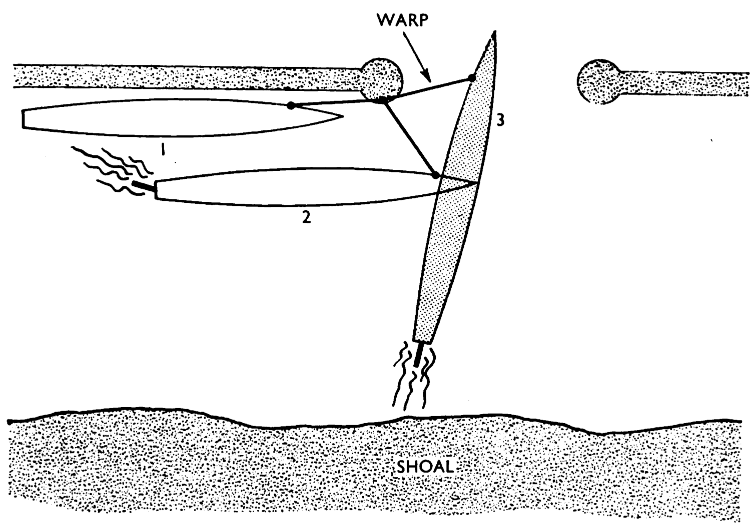

Fig. 13–30. Warping a ship through a narrow entrance

If there is a cross wind or stream the approach should be made from a point upstream or upwind to allow for leeway during the approach. If the approach is made crabwise to allow for the cross current, a sharp swing using full wheel may be necessary as the ship reaches the entrance to keep her stern and bows clear of the piers. This need will almost certainly be reinforced by the fact that

the bows, on reaching the point between the pierheads, will probably enter slack water, or be sheltered from the wind, so that the stern will be carried rapidly downstream or downwind if no remedial action is taken (fig. 13–31, position 2). The advantage of keeping up a reasonable speed if possible during the manœuvre is obvious.

Dredging an anchor, as described earlier in this chapter, may be a helpful expedient when passing through a narrow entrance. (See page 294.)

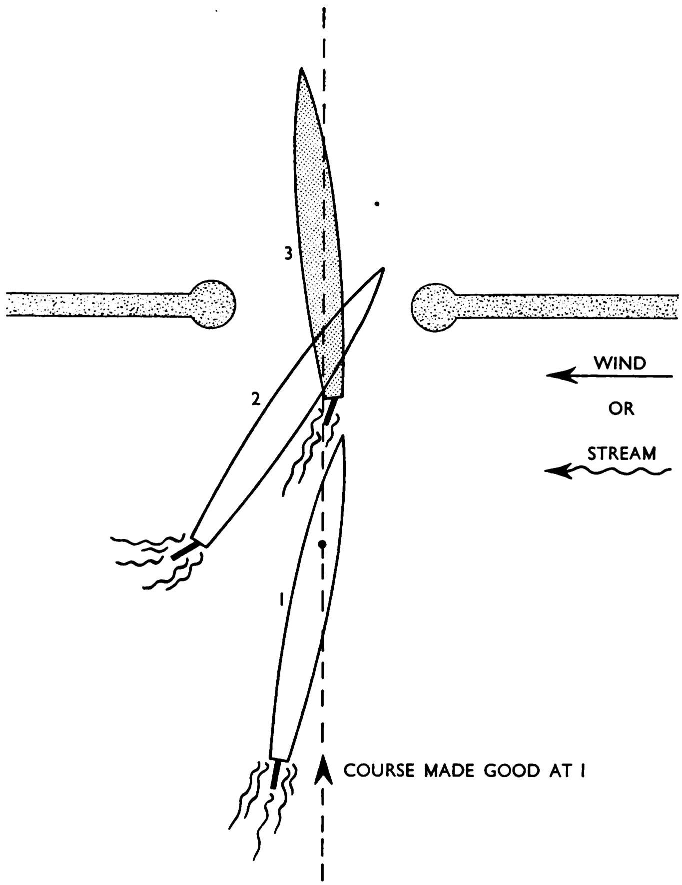

FIG. 13–31. Passing through a narrow entrance with a cross wind or stream, or both

PASSAGE THROUGH CANALS, RIVERS AND NARROW CHANNELS

The effects of shallow water on the speed and steering of a ship, described in Chapter 12, are intensified in a canal or similar narrow shallow passage, because the movement of water around the ship is confined. A ship moving along a canal pushes ahead of her a volume of water proportionate to her size and speed. A

lateral wave is formed just ahead of the ship, constituting a zone of increased pressure (fig. 13–32). Just astern a similar but smaller wave travels along with the ship. Between these two waves there is a trough along the length of the ship constituting a suction zone. Anything floating is repelled by the wave at the bows, and similarly the bows of the ship itself are repelled from anything solid such as the canal bank. The suction zone tends to attract any floating thing towards the sides and quarters of the ship, and also to cause the after part of the ship to be attracted towards the bank. The water level in the canal ahead of the ship is

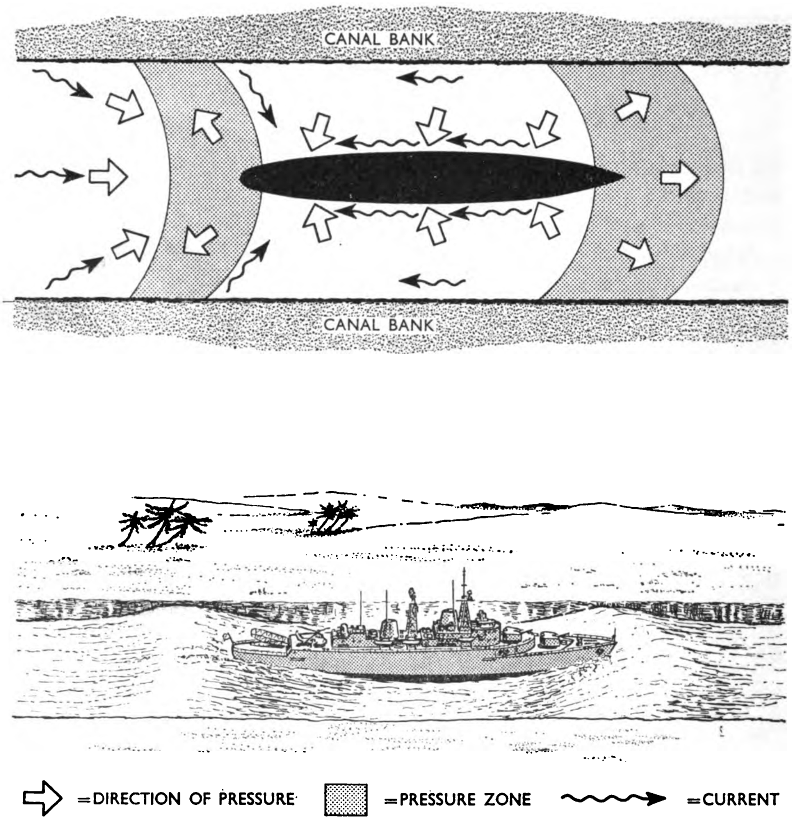

FIG. 13–32. Zones of pressure and suction caused by passage of a ship through a canal

raised, while astern of her it is lowered. If speed is increased and the depth and width of the canal are little more than the draught and beam of the ship, the effects are noticeable a long way ahead and astern of the ship. It is on record that a ship proceeding at excessive speed in the Manchester Ship Canal parted the hawsers of a ship moored three miles ahead.

Effect of canal on ship's speed

To maintain the level of water in the canal an opposing current is set up that flows rapidly past the sides of the ship (fig. 13–32). This current is strongest

close to the ship and near the surface, and weakest at the bottom of the canal and near its sides. Combined with the shallow-water effect, this opposing stream retards the ship's progress. For example, a heavy ship passing through the narrow sections of the Suez Canal may make good only 5 knots at revolutions for 7 knots, while passage through the Gaillard Pass of the Panama Canal may reduce the ship's speed by as much as 40 per cent.

To prevent damage to the banks and to craft moored, a speed limit is imposed in canals and in many rivers, and this must be rigidly obeyed. If the draught is such that there is only a little water under the keel, the ship's speed should be kept well down, and a careful watch kept on the state of the wave formation caused by the ship's passage. An increase in the bow and stern waves indicates that the ship is going too fast. She tends to settle deeper in the trough, and her speed may drop suddenly, causing the stern wave to overtake the ship and render the steering uncontrollable. The same effect may occur when the revolutions are reduced rapidly, so it is all the more important not to go too fast, and, if obliged to reduce speed, to·do so gradually if possible.

To sum up, a ship when in a canal has a critical speed above which her steering becomes increasingly erratic because of the shallow-water effects. This is known as the *canal speed*, which cannot be exceeded with safety.

Effect of canal on ship's steering

So long as the ship remains in the centre of the canal the pressure distribution is equal on either side of the ship; the steering will not be affected and little wheel should be required to keep her on course, provided that the canal is of symmetrical cross-section. The fact that little wheel is being used indicates that the ship is following the best track in a canal or narrow passage. Conversely, the need to apply a large amount of wheel to keep on course shows clearly that the pressure distribution is unequal. This may occur either because of the configuration of the bottom, or simply because the ship has approached too close to one bank. The danger is that the pressure from this bank against the bows, combined with the attraction of the after part of the ship to that bank, will throw the bows off this near bank and cause the ship to sheer violently over towards the opposite bank (fig. 13–33).

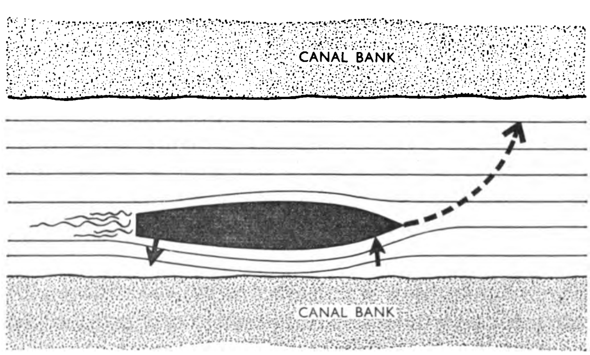

FIG. 13–33. Start of a sheer caused by a ship approaching too close to a canal bank

Correction of a sheer in a canal

The use of the wheel alone may be quite insufficient to correct such a sheer, hence the shiphandler should be ready to use the engines on the instant, or to let go an anchor immediately, if the need arises. In a multiple-screw ship it has been shown by experiment and by practical experience that the best method of breaking a sheer is to increase the speed of the screws on the side towards which the ship is sheering and to reduce speed, or even stop the screw, on the other side (fig. 13–34). But unless the initial speed of the ship is low, even drastic alterations of revolutions may have little effect. Experiments have further shown that it may be less effective to reverse the engine on the side away from the sheer than merely to stop it. There is also the danger of damaging the propellers by swinging the stern too close to the bank. Meanwhile the rudder may be entirely ineffective in checking the sheer, and, if so, the anchor opposite the direction of sheer should be let go and dragged at short stay (fig. 13–34).

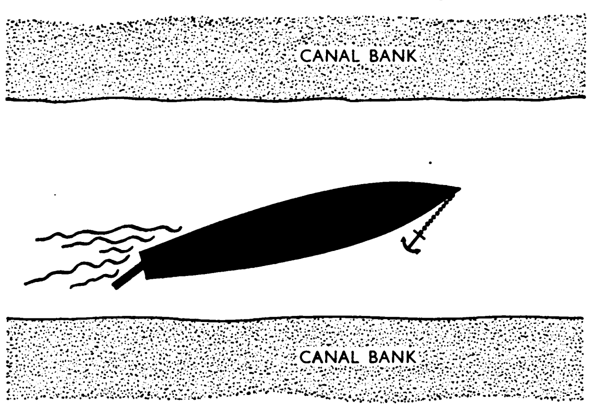

FIG. 13–34. Action required in a multiple-screw ship to check a sheer to port in a canal

In a heavy ship, if prompt action with the engines and rudder as described has failed to have any effect on the sheer, it is probably best to reverse all the engines immediately at full power in order to take the way off the ship, and if necessary also to let go both anchors. If this is not done by the time the sheer has carried the bows past the centre of the channel it is unlikely that the ship can be prevented from striking the opposite bank.

In smaller single-screw ships a sheer is best checked by full ahead revolutions and full rudder, but on occasions the sideways force of the propeller when going astern may be used to prevent the stern swinging on to the starboard bank.

In any ship quick judgment is necessary when correcting a sheer to ensure that the correcting action is removed and possibly countered as soon as it begins to take effect; otherwise it is quite easy to produce a sheer in the opposite direction and ground the ship on the bank from which she was originally swinging away.

Smelling the ground

The effect of water pressure against the bows from the presence of shelving water on one side, causing the bows to swing away into deeper water, is the phenomenon known as *smelling the ground.* In a narrow passage or canal it can produce a dangerous sheer towards the opposite shore or bank, but it can be beneficial if the water opposite the shoal is deep and safe. The effect is most marked if the bottom shelves steeply, as shown in fig. 13–35.

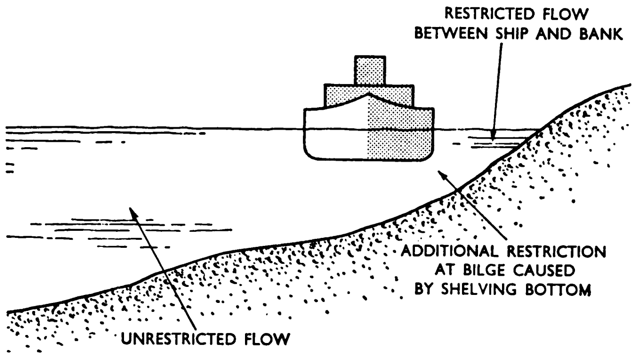

FIG. 13–35. The phenomenon of 'smelling the ground' is accentuated by a shelving bottom

Rounding a bend where there is little current

As the ship approaches a bend in a canal or river there will be a tendency for the bows to smell the ground on the outer bank and so to be swung round the bend. In negotiating a bend it may be found that it is unnecessary to use any wheel towards the direction of the bend, because the water pressure on the outer bow will be just sufficient to carry the ship round. In fact, if the ship approaches the bend on the outer side of the channel it may be necessary to use opposite wheel to keep her safely in the channel as she rounds the bend. If she approaches the bend too close to the inner bank there is a danger that she may take an uncontrollable sheer towards the outer bank. Nice judgment is therefore required in selecting the best course to follow and if there is little current it is generally advisable to keep to the centre of the channel, but inclining slightly to the outside of the bend, when it will often be found that very little rudder is required to negotiate the bend.

Negotiating a bend in a strong current

If there is a strong current or tidal stream running round the bend, as is often the case in rivers and estuaries, its effects may be quite opposite to those caused by smelling the ground. On the straight reaches in a river the current usually runs more strongly in mid-channel than at the sides; but on bends the current normally runs strongest and deepest along the outer bank of the bend, and there may be slack water, or even a reverse current, along the inner bank.

When rounding a bend upstream the current may tend to throw the bows outwards, as shown in fig. 13–36, thus counteracting any tendency of the water

pressure to push the bows off the outer bank. One must be prepared in such a case to use wheel boldly in the direction of the bend, and one must avoid approaching too close to the inner bank. When coming downstream, particularly if the approach has been made somewhat on the inner side of the bend, there may come a time when the current is tending to push the stern strongly towards the outer bank (fig. 13–37). It may therefore be necessary to use opposite wheel to forestall this, or at least to apply early the opposite wheel needed for steadying the ship on the next straight reach. Again any tendency to 'smell' the inner bank may be overcome by the outward pressure of the current on the stern. The degree to which these effects of current are felt depends on the length of the ship in relation to the width of the navigable channel.

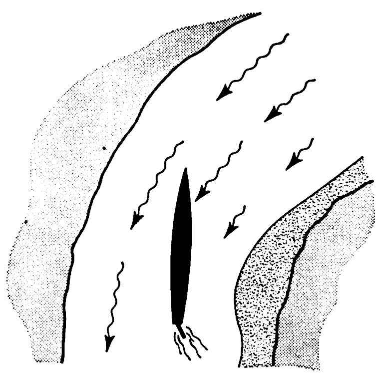

FIG. 13–36. Passage round a bend upstream

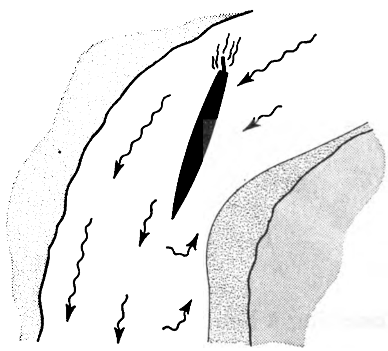

FIG. 13–37. Passage round a bend downstream

A pilot's knowledge of local effects in rivers and canals is often invaluable.

It is a fairly general rule that ships should not pass each other on sharp and narrow bends.

Effect of wind when rounding a bend

A wind may, according to the direction in which it is blowing, tend to increase or decrease the swing of a ship as she turns round a bend. Probably the most difficult situation is that of a lightly-laden single-screw ship proceeding down river and before the wind, when negotiating a sharp bend to starboard. As the ship turns round the bend both the current and the wind tend to swing her stern towards the outer bank; if this swing gets beyond control it will be useless to reverse the screw, because the sideways force of the propeller will only accentuate the swing. But if the rate of swing is kept firmly under control at the start all should be well.

Two ships meeting in restricted channels and canals

When two ships meet in a restricted channel, rather than incline much towards their respective sides they should steer to pass close to each other. With care there is little possibility of accident, because as they close the water pressure between them will force their bows apart; on passing they will tend to parallel

each other; and when separating their sterns will be drawn together. These influences will thus counteract the effect of the nearer bank, and the two ships should have no difficulty in regaining the centre of the channel.

In broad and deep canals ships going in opposite directions may be able to pass each other while both are under way, but usually one of the ships must make fast to the bank to allow the other to pass her. In some canals—the Suez Canal, for example—the bank is cut away at intervals to form sidings in which a ship can make fast.

Making fast to the bank. A ship is made fast to a canal bank in much the same way as she is secured alongside a jetty, except that the way of the ship is reduced very gradually to stop her abreast the berth with as little astern movement of the engines as possible. Plenty of time should be allowed for the manœuvre, and it is usual to begin reducing speed when the ship is about a mile from the berth. An unhandy ship is usually stopped in the centre of the canal and then warped alongside the bank by means of her hawsers. Easily-handled ships can be manœuvred closer to the bank before the hawsers are sent ashore; but great care must be taken, particularly in multiple-screw ships, to avoid getting the stern too near the bank and so endangering the rudder and inshore propellers. Except in a current or strong head wind, two breastropes should be sufficient to hold the ship in her berth.

Effect on the berthed ship when another ship passes. A berthed ship will surge considerably in the wash of a passing ship, and no hawsers will be able to hold her steady. The berthed ship should therefore be free to move as the other passes her, and her hawsers should accordingly be slackened right off as the passing ship approaches. Assuming the berthed ship lies bows towards the approaching one, the effects of the passing ship's bow wave, trough and stern wave on the berthed ship as they reach and pass her are as follows: First, the berthed ship's bows are repelled towards the bank as the bow wave reaches her; she then surges ahead in the current of the trough and her bows are drawn away from the bank by its suction while her stern is pushed towards the bank by the bow wave; as the stern wave reaches her bows her movement ahead is stopped, and at the same time her stern is sucked out from the bank by the trough; finally, as the stern wave passes her stern, the ship surges astern and tries to follow in the wake of the passing ship (see fig. 13–32).

This surging must be controlled by the engines and rudder to prevent the stern from being drawn too far out from the bank and colliding with the quarter of the passing ship, and also to prevent the berthed ship from surging too far astern. The surging can be controlled quite easily by a kick astern and then a kick ahead on the engines, with the wheel put over away from the bank. In twin-screw ships only the offshore propeller should be used.

Course of the passing ship. The passing ship should approach along the centre of the canal at slow speed, and should endeavour to keep along the centre of the canal as she passes the other ship, even though it entails passing close aboard of her. Even if the course of the passing ship would appear to take her too near the berthed ship, the ships will in fact sheer away from each other; whereas if the passing ship attempts to give the other a wide berth, she may then come under the influence of the far bank of the canal and take a sheer towards the berthed ship, with dangerous results.

DOCKING AND UNDOCKING

The operations of docking and undocking ships described here are those carried out in the Royal Dockyards; the methods used by other yards are, in general, very similar.

Conditions required

In tideless waters, or in a basin, a ship can be docked or undocked at most times. In tidal waters, however, the docking and undocking of a ship depend upon the depth of water over the sill of the dock and upon the state of the tide, and the operations are usually begun from 3 to 4 hours before high water, so that the ship can be docked or undocked and the dock gates be closed at, or just before, the time of high water.

At some ports—Chatham river docks, for example—the neap rise may give insufficient depth of water over the sill of the dock for certain ships to be docked at that tidal period.

Preparation in the ship

All fairleads and bollards should be clear and ready for taking the docking-hawsers, and bollard strops and slips should be provided forward and aft. Each part-of-ship should provide at least four heaving lines, two on each side; and though it is customary for the Dockyard to provide the docking hawsers, the ship's berthing hawsers should be ready for use. The ship's side should be clear of obstructions which might interfere with the handling of hawsers; all side-scuttles and ports should be closed, accommodation ladders hoisted inboard, davits and boats turned in, and all cranes, derricks and boat-booms should be housed. Awnings should be furled, the anchors hove home but otherwise ready for letting go, and any retractable underwater fittings, such as sonar domes and bottom-logs, should be housed.

It is essential that the ship should have no list before docking. She should be trimmed either level or slightly by the stern, as directed by the Dockyard officers.

A berthing party may be required by the Dockyard to assist in handling the hawsers; if so, it should be sent to the dock before the ship leaves her berth.

Docking hawsers

The hawsers usually required for docking a ship are listed below. They are passed in pairs, one on each side (the weather one first), in the following order:

1. *first fore-guys*, which are led through the foremost bow fairleads;
2. *docking-springs*, which are led from ahead through the fairleads abreast the break of the forecastle or just before the bridge; in small ships such as frigates, however, one docking-spring only is passed, and it is led from right ahead through the bullring;
3. *second fore-guys*, which are led through the fairleads abreast the bridge;
4. *first after-guys*, which are led through the fairleads abreast the after superstructure or near the after gangways;
5. *second after-guys*, which are led through the aftermost quarter fairleads.

The springs are used to warp the ship ahead, and the guys to square the ship so that she lies along the centre-line of the dock. The after-guys are also used to take the way off the ship, and it is important that when these are passed they should be secured as quickly as possible, because this is a critical stage of the operation.

Preparation in the dock

Flat-bottomed vessels are sometimes built with side docking-keels, and for such vessels three lines of keel blocks are provided, but no bilge or breast shores except when they are placed in a floating dock. For vessels with rising bilges one line of keel blocks and bilge and breast shores are provided. The keel blocks are laid along the bottom of the dock and the shores are laid on the dockside within reach of a dockside crane. Breast shores are provided with lanyards at each end to enable them to be floated to their positions and manhandled into place.

Stars, each with the name of the ship, are painted on each side of the dock, two forward and two aft, to indicate the exact position in which the stem and the stern of the ship should be. Other marks may also be painted on the dockside to indicate such positions as those of the 'cut-up' (the after end of the keel), the propellers and the sonar dome.

Catamarans with brooms and scrapers are provided for the men who scrape the ship's bottom as the dock is pumped dry. The docking hawsers are provided, and light tripping lines are rove across the dock at intervals to keep the bights of the fore-guys and springs clear of the bottom of the dock as the ship is warped in; they are tripped and hauled clear as the ship approaches them. Other gear provided includes: tackles, slings, and strops for the shores; docking tackles, which are clapped on to the guys and used to square the ship in her correct position as the dock is pumped out; and plumb-bobs and docking-bobs, which are used to ensure that the ship is upright and in her correct position.

When preparations are complete, the dock is flooded to the same level as the water outside, and the caisson is then removed or the dock gates opened. A diver is usually in attendance while docking.

Entering the dock

The ship is towed from her berth to the dock, the number of tugs varying with the size of the ship. For a cruiser three tugs are usually employed, one ahead, one astern and one secured alongside amidships. A pilot is usually in charge and the ship is manœuvred by the tugs alone. If her engines are used at all it is only during preliminary manœuvring and in emergency.

The ship is headed for the dock entrance and then placed by the tugs with her bows just inside the entrance and pointing directly up the centre-line of the dock. The fore-guys are then passed and secured, and the ship is warped into the dock while the tugs at her quarters help to keep her stern in the correct line.

If the fairway opposite the dock is narrow and a tidal stream is running across the dock entrance, the ship may be placed alongside the dock wall just upstream of the entrance and heading downstream, with a tug secured to her inshore quarter (fig. 13–38). A hawser is then passed from the tug to a bollard upstream of her, and the first fore-guys and springs are passed to the ship and secured.

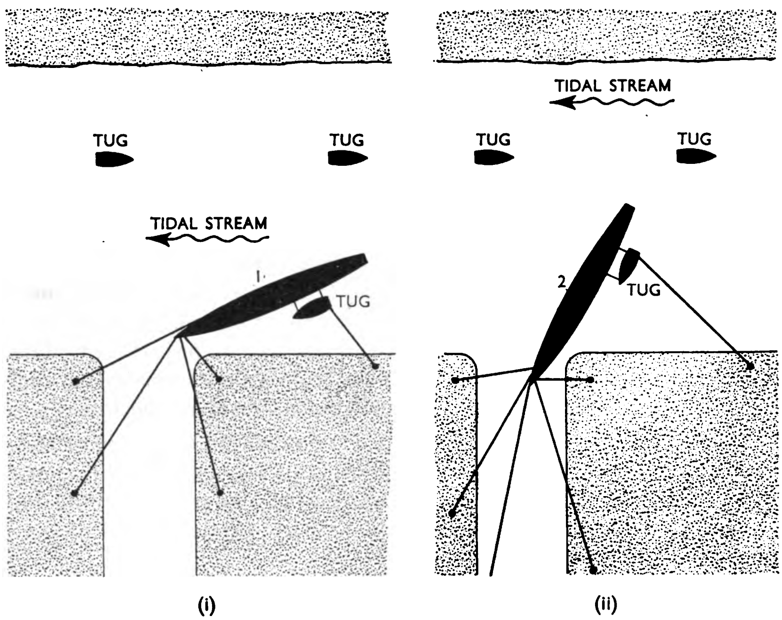

FIG. 13–38. Warping a ship into a dock entrance when a tidal stream is running across it

The tug then surges her hawser, thus allowing the stream to swing the stern of the ship out from the wall, and at the same time the bows of the ship are warped round the knuckle of the dock while the tugs help to keep her correctly positioned.

Docking

From the moment the first fore-guys are secured in the ship the representative of the Captain of the Dockyard (normally the Master Rigger) is responsible for positioning her in the dock to the satisfaction of the officer in charge (normally a Constructor Officer). The docking-springs are taken to capstans at the head of the dock, and the guys, which are passed successively in pairs as the ship is warped through the entrance, are taken to bollards on each dockside. The Master Rigger signals his requirements by whistle and handflags to the men working the hawsers and capstans and to the pilot in charge of the tugs. As the ship is warped up the dock by the springs the guys are taken forward from bollard to bollard and worked as required to breast the ship squarely in the dock, and just before the stern passes over the sill the tugs are cast off.

When the stem of the ship is a few feet from the stem-marks this fact is signalled to the officer-in-charge of docking, who then brings up the ship on the guys. Finally, the ship is squared off in her correct position by the guys and springs and then secured by two fore-guys (one on each bow) and two after-guys (one on each quarter). One or two brows are then placed by a dockside crane.

Docking-down

When the Constructor is satisfied that the ship is correctly placed in the dock, he takes over the charge of operations and orders the docking-tackles to be rove.

The docking-tackles are hooked on to the middle of the spans of the two fore-guys and the two after-guys, and then led at right angles with the guys to bollards on the dockside and set up. The ship's position in the dock can be very accurately adjusted in this manner and she can be securely held there by keeping the guy tackles taut.

A diver may be sent down to ensure that the grooves in the sill of the dock are clear, and the caisson is then replaced. *Sewing marks* are then chalked on the stern and on each side of the stem, one on the waterline and one six inches above it; these indicate the fall of water after the ship has been *sewed* (grounded) on the keel-blocks. Plumb-bobs are rigged in hatchways or trunks forward and aft in the ship to check that she is upright, and docking-bobs are rigged over the centre-line of the dock, just before the stem and just abaft the stern of the ship, to check that the ship is lying along the centre-line of the dock as she is sewed. (The docking-bob is a light wire rigged across the dock with a ring at its centre; the plumb-line is rove through the ring and tended on the dockside, and its length is adjusted so that the tip of the bob is kept just immersed.)

All brows, except one which is slung on a crane, are now removed and the officer-in-charge then gives the order to start pumping. He usually stations himself on the caisson where he can keep in touch with the ship's officers, see the after sewing and draught marks and the dock water-level marks, and note the general progress of the operation.

If breast shores are used they will have been cut to the required length and marked beforehand. They are then floated in the water to their approximate positions, their heads being adjusted by tackles to coincide with positions chalked on the ship's side, and their heels being kept in position by lanyards until they rest on the dock 'altars' (steps).

When the keel of the ship is about two feet off the blocks pumping may be stopped and a diver sent down to ensure that all is clear. Pumping is then resumed, and when the water is seen to leave the forward and after sewing marks, thus denoting that the full length of the keel is sewed, pumping may again be stopped and the breast shores (if used) finally adjusted and set up. The shores are all set up simultaneously, when ordered by the officer-in-charge, by shipwrights who drive wedges between the heels of the shores and the dock altars. The catamarans are then manned by the ship's company. They paddle them to positions round the ship's side and start scrubbing and scraping the ship's bottom as the water falls. The rate of pumping is adjusted to ensure sufficient time for the bottom to be thoroughly cleaned. As the water level falls the crews should take care that their catamarans do not ground on the propellers, propeller shafts or dock altars, because a catamaran thus grounded entails reflooding the dock and so wasting time.

As the seacocks for flooding compartments such as magazines and the spirit room are uncovered, their gratings are removed by the ship's engineers, flooding-bonnets are fitted over them, and hoses connected from the bonnets to the dockside hydrants. Pumping may be temporarily stopped to enable this to be done.

When the dock is pumped out dockyardmen cut up and erect any bilge or bottom shores required. The docking tackles are then unrove, and if breast shores are used their head tackles are replaced by lanyards.

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The brows are then placed in position and secured, and hoses and cables are connected between ship and shore to provide fresh and salt water, electricity, telephonic communication and earthing arrangements.

Flooding-up

The day before a ship is due to be undocked, and before flooding operations are begun, the Undocking Certificate and the Certificate of Changes of Weight in Dock must be completed and forwarded by the Commanding Officer of the ship to the Manager of the Constructive Department of the Dockyard.

The *Undocking Certificate*, which is signed by the Commanding Officer, contains statements to the effect that the various underwater fittings of the ship, such as seacocks, bottom-logs, sonar domes, submerged torpedo-tubes and their sea connections, are shut and in good working order, these statements being signed by the officers responsible for the fittings.

The *Certificate of Changes of Weight in Dock* is also signed by the Commanding Officer, and contains details of all changes of weight which have been made in the ship while she has been in dock. If any changes are made after the certificate has been forwarded, full details must be forwarded immediately to the Manager of the Constructive Department, and the changes must be approved by him before flooding of the dock is begun.

Before flooding is begun, bottom and bilge shores and any staging are removed, and any arisings are cleared from the dock. Catamarans are secured to prevent them from damaging the ship or themselves when the floodwater rushes into the dock. Hoses and cables carrying shore supplies are either disconnected or slacked off to allow for the rise of the ship in the dock; all brows, except one which is slung on a crane, are removed; the docking tackles are re-rove on the fore- and after-guys, and the docking hawsers are passed and rove.

When all is ready the Constructor who is in charge of this stage of the operation gives the order to flood the dock, and the penstocks are opened. As the ship lifts off the keel blocks the docking tackles are worked to keep her in the correct position, and any breast shores used will float clear, their heel lanyards being tended to keep them from fouling obstructions as the water rises in the dock. When the level of the water inside the dock is the same as that outside, the caisson is removed and the docking tackles unrove, and charge of the operation is handed over to the representative of the Captain of the Dockyard.

Undocking

The ship is warped to the entrance by the docking springs, which are led aft from the ship to the dockside capstans, while the guys are worked to keep her in the middle of the dock. As her stern reaches the entrance, tugs are secured and tow her clear, the guys being cast off as ordered by the officer in charge of undocking. As soon as the last guy is cast off the manœuvring of the ship is under the charge of the pilot, and he gives the necessary orders to the tugs to tow her to her berth.

Floating docks

When a ship is docked in a floating dock the disposition of her weight in the dock must be very carefully considered, both to avoid straining the structure of

the dock and to preserve its stability. The displacement and trim of the ship, and the distribution of weight in her, must therefore be adjusted beforehand to the requirements of the Constructor Manager.

The ship is placed in the dock so that her centre of gravity lies directly over the centre of buoyancy of the dock. The position of the ship's centre of gravity is obtained from the ship's docking plans and then indicated by a mark painted on each of her sides, and the position of the dock's centre of buoyancy is marked on each side of the dock.

In other respects the operations of docking and undocking are very similar to those for a dry dock.

Docking small vessels with considerable trim

Vessels such as tugs, trawlers and drifters, whose draught forward differs considerably from their draught aft, require extra care when being docked down. When the after end of the keel touches the keel-blocks the vessel is 'pinned' in position by breast shores placed immediately above the point where the keel touches the blocks. The shores are not set up, but are held lightly in position to steady the ship until the keel is sewed for its full length; then the remainder of the breast shores are placed, and all are set up together.

Docking destroyers or frigates

Particular care is necessary when docking down a destroyer or frigate to ensure that her rudder and propellers are not damaged by the keel-blocks. The ship should be trimmed only slightly by the stern, and each propeller should be turned so that one of its three blades is at '12 o'clock'.

Destroyers whose fuel and ammunition have been disembarked are liable to be rather tender, and particular care should therefore be taken to ensure that no weights are moved on board when docking or undocking, and that the Certificate of Changes of Weight in Dock has been accurately compiled in every detail.

Docking submarines

The Commanding Officer of a submarine must first inform the officer in charge of docking-down or flooding-up that his ship is in the required state of trim, and during these operations he should not alter the trim without consulting the officer-in-charge. Before entering the dock it is usual to blow all main tanks and leave the main tank Kingston valves open until the ship is docked-down; before flooding-up, however, the main tank Kingston valves are closed.

Breast shores are placed where the hull is broadest, and as these positions are usually under water when the vessel is sewed, steadying shores are placed against the casing to keep her upright until the breast shores are in position and set up. Steadying shores are also placed before flooding-up and kept in position until the vessel is fully afloat.

ACTION IN EMERGENCY

In the various manœuvres covered in this chapter it has been shown how, in order to keep the ship under the control of her captain rather than under the dominance of wind or current, it is necessary to plan fully in advance, to use moderate speed, to employ warps and anchors when necessary, and not to despise the assistance of pilots and tugs. In short, when manœuvring in narrow waters prevention is better than cure. If, however, the shiphandler starts to lose control there is often some emergency action that will enable him to reimpose it. If it is to be effective this action must be applied quickly and resolutely. The action usually available is the use of full rudder, or the use of full power ahead or astern on the engines, or letting go an anchor.

The quick effect of a burst of power ahead on the engines with the wheel hard over must be appreciated. To start a ship swinging in the desired direction, or to stop her swinging in an undesirable direction, this action is usually far quicker in its effect in a multiple-screw ship than to go astern on one side and ahead on the other, particularly in shallow water. The headway gained at first is not very great. But, of course, if full power ahead or astern is used, the shiphandler must watch the ship like a hawk and take off the power almost before it has begun to have effect. Otherwise he will soon find that the ship is shooting ahead or astern and getting into worse difficulties than she was in before.

Finally, even when an accident appears inevitable there is usually some action that can be taken to minimise the damage. This is one reason why every seaman should have a good knowledge of the construction of his ship, and hence of how she can best withstand an impact. Consider the following:

1. If the choice lies between colliding with another ship and running aground, it may be preferable to go aground and thus confine the damage to one ship. This applies particularly to ships carrying dangerous cargoes.
2. The most vulnerable parts of a ship's hull, and those where extensive damage is most difficult to repair, are the bilges, the propeller shafts with their 'A' brackets, the propellers and the rudder. If grounding is inevitable it is therefore preferable to ground head-on than to attempt to turn and so risk ripping open the bottom of the ship.
3. If collision with another ship is inevitable the damage can be minimised by striking her a glancing blow, preferably bow-to-bow, quarter-to-quarter, or bow-to-quarter. Striking the other ship head-on amidships or turning athwart her bows and so allowing the other ship to strike yours amidships must, if possible, be avoided. A ship is very vulnerable amidships, because any serious underwater damage there will flood her largest compartments, i.e. the boiler rooms and engine rooms, and when these are flooded the ship may founder.
4. There should be no hesitation in using anchors in an emergency to check a ship's headway, or to turn her, or to prevent her from drifting on to a lee shore.
5. If collision with a jetty is unavoidable, it is better to turn and strike it a glancing blow then to strike it head-on. The resulting damage will probably be above the waterline and not so extensive as that caused by a head-on collision.

CHAPTER 14

Handling Ships in Company

Warships often operate in groups rather than singly. The arrangement of ships in a group may be such that ships are spaced several miles apart; or they may be only a few cables apart; or—when replenishing at sea, for example—they may be as little as 50 ft apart when steaming close aboard.

Definitions

A single ship, or a small number of ships operating as an entity for manœuvring purposes, is called a *unit*. An ordered arrangement of two or more ships or units proceeding together is called a *formation*, while an ordered arrangement of two or more formations is called a *disposition*. The ship on which other ships take station when forming up, or keep station when formed up, is called the *guide*. Thus there will be a guide for each disposition, but there will be also *formation guides* in each formation.

When ships are formed along a straight line in any direction they are said to be in a *line*, and at one end of the line will be the *line guide*. If the ships in the line are formed directly ahead or astern of the line guide, they are said to be in *column*, if directly abeam of the line guide they are in *line abreast* and if on some line other than directly ahead, astern or abeam of the line guide they are said to be on a *line of bearing*.

Fundamentals of manœuvring in company

Close formation may be required when entering or leaving harbour, on ceremonial occasions, or for certain operations in war. But it is also frequently exercised in a fleet at sea because it is an excellent means of training in ship-handling and provides an opportunity for officers to develop initiative, good judgment, confidence and comradeship.

To be successful at handling your ship in company you must cultivate a trained eye so that you can judge accurately relative distances, courses, speeds and rates of turning. You must have a thorough knowledge of the manœuvring capabilities of your ship and of all the instructions about the conduct of a fleet or convoy, so that you will be able to act with rapidity and certainty. Above all, you must always consider your obligations to adjacent ships, particularly to ships astern of you. In the days when heavy ships almost always steamed in column it was the custom to place a large notice in the forepart of the bridge, bearing the words: REMEMBER YOUR NEXT ASTERN. You will learn undoubtedly from the mistakes of your next ahead how best you can help your next astern. If your ship is the guide, particular attention should be paid to the steering and to keeping the revolutions ordered both accurate and steady. The fact that ships astern of you appear to be steering badly or are out of station may be the fault of your own ship.

STATION-KEEPING

Station-keeping when in line or column

Ships in line keep station on the line guide, that is, each ship should maintain the correct bearing and distance from the guide. But in endeavouring to do so a ship is bound to be influenced by the behaviour of the other ships in the line between her and the guide. Bearing and distance are always measured from the foremast of the guide to the foremast of the ship keeping station, or, in the case of ships without foremasts, between the navigating bridges of the two ships. A ship at the end of a line of bearing may find difficulty in observing bearings and distances of the guide, because the guide is obscured by intervening ships. Obviously, in keeping her correct station the end ship will be influenced by her bearing and distance from the ship next to her. If all ships in the line were, for example, slightly outside distance, it might be impossible for the end ship to keep correct distance from the guide without getting dangerously close to her adjacent ship.

Thus it is clear that one or two ships who are lax in keeping station will not only destroy mutual confidence in the line, but may positively endanger other ships.

In modern heavy ships the primary steering position is invariably below armour, and the ship must therefore be conned always by the Officer of the Watch. Station is best kept in column by ordering the quartermaster to steer a course that will maintain the correct compass bearing of the foremast of the column guide.

In small ships where the quartermaster has a view it is usually best to order him to follow the column guide and not to endeavour either to keep in the wake of the next ahead or to keep the masts of the column in line. This will prevent the development of a cumulative 'snaking' of the line caused by rear ships slavishly following the unintentional wanderings of those ahead.

Accuracy in keeping station

It is evident that accuracy in station-keeping is essential, not only for smartness but also for the safety of ships concerned. In certain cases it is directly related to operational efficiency. For example, gaps may be left in sonar screens against submarines through bad station-keeping. The efficiency of minesweeping when in formation, and the safety of the sweepers themselves, depend directly on the maintenance of accurate station.

As Officer of the Watch you should try to keep station with the smallest possible alterations of speed and course, but this can be done only if such alterations are applied very promptly, as soon as the ship begins to get out of station. Alterations in speed of from one-third to half a knot and of from 2° to 5° in course should suffice in calm weather. But do not shrink from taking much more resolute action if you appear to be getting rapidly out of station. If you are as much as one cable out of station you will not be justified in taking ten minutes to creep back. Remember that to change the station of a ship by one cable in six minutes her speed must be altered by one knot from that of the column.

Large ships steaming at slow speed—and all ships steaming into steep head seas—will require larger alterations of speed and course than are adequate to keep station normally. Small ships are more affected than heavier ships by the wind, the sea and the wash of the next ahead, and in them it is better to use larger but briefer alterations of speed.

Methods of keeping station

The bearing is normally measured from the azimuth circle on the Pelorus, which is the central gyro-compass repeater on the compass platform. The Officer of the Watch should know if there is any error at the Pelorus and must apply it as necessary when keeping station. Since distance when stationed is measured between foremasts, allowance must be made for the position of the measuring instrument in the observer's own ship and the position of the object being ranged on in the other ship. Information about ranging instruments used for station-keeping is given in B.R.45(1), *Admiralty Manual of Navigation*, Vol. I. When using a vertical angle from some high object, such as the truck, to the waterline it is necessary to observe the waterline at a point immediately below the high object. When in column this point cannot be seen, but some equivalent level can be selected by eye. Alternatively, the waterline may be neglected and any two well-defined marks, such as the main truck and the deck level at the stern, used.

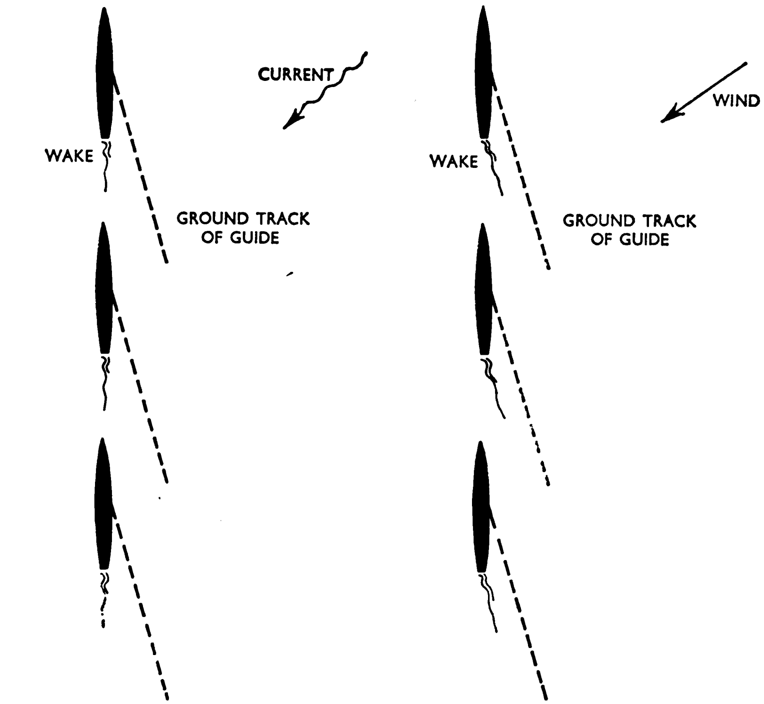
Radar is frequently employed for keeping station, particularly when steaming at night without lights. At times sonar may also prove helpful. But on occasions the operation of either may be prohibited, and officers must be capable of keeping station in column at night by other means. One method is to observe the size of the ship ahead in the field of your binoculars, and act as necessary as soon as it begins to increase or decrease. Provided you keep in the same place on the bridge, you can in calm weather get an early indication of opening or closing by watching for any movement of your own forecastle up or down relative to the wake of the next ahead.

Speed flags

In order to facilitate station-keeping, a ship may indicate her speed by small-size numeral flags displayed from the wing of the bridge. They are informative only, and are never used to signal changes of speed. An alert Officer of the Watch makes use of any visual indications of a change of speed, such as a change in the wake or a puff of smoke, and also of audible ones, such as a change in the noise of boiler-room fans.

Keeping station in column in a narrow channel

When proceeding along a narrow channel in a strong beam wind or cross current, you should steer so as to make good a course down the centre of the channel. If ships follow in the wake of their next ahead the line will sag to leeward and the rear ships may be in danger of grounding, or, in a swept channel, of striking mines. Ships in column may be ordered to maintain compass bearings and distances from the guide, but the guide is not obliged to make such an order, because captains are always individually responsible for the safe navigation of their own ships.



(i) Effect of cross current on track and wake
(ii) Effect of cross wind on track and wake

FIG. 14–1. Effect of cross current and wind on ships in column

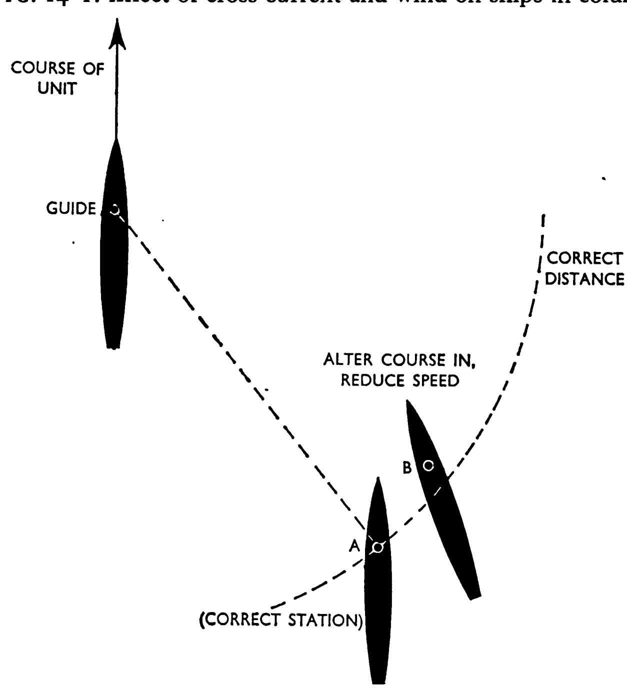


FIG. 14–2. An example of how to regain station when on a line of bearing

It is of interest to note that if there is a cross current or tidal stream the wakes of the ships in a column do not give a true indication of the tracks made good over the ground. On the other hand, if there is only a cross wind the wakes do lie along the ground tracks of the ships (fig. 14–1).

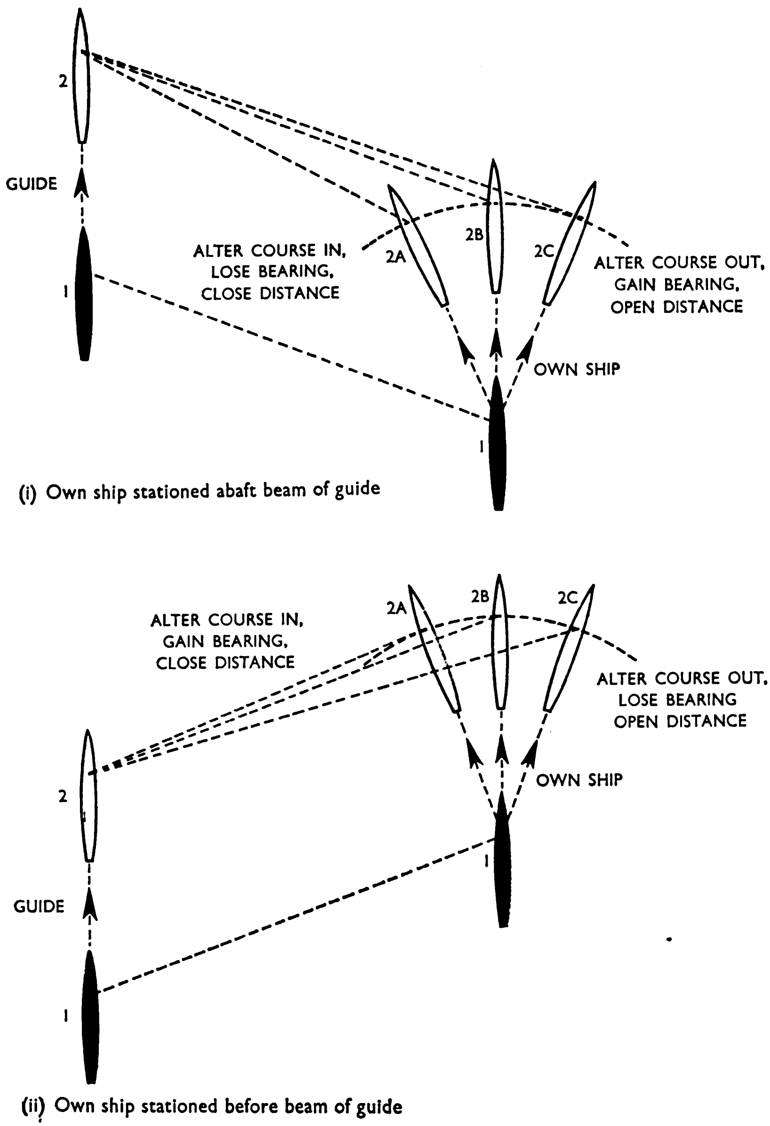


FIG. 14–3. Effect of alterations of course at steady speed when keeping station on a line of bearing. In each case the position 2B shows the result of keeping steady course, 2A that of altering course inwards, and 2C outwards

Keeping station on a line of bearing

When in column the bearing of the guide does not tend to change rapidly, and the chief problem is how to maintain correct distance. When stationed on a line of bearing, a small discrepancy in course or speed from that of the guide may result in a fairly rapid change of bearing, as well as a change of distance. If you plot your own position relative to the guide on a manœuvring form (S.376) or on the Battenberg Course Indicator you will see much more easily what action is necessary to regain station. In fig. 14–2 the correct station of a ship relative to the guide is shown at A. If observations show that the ship has gained bearing and is inside distance it might be assumed, without plotting, that the correct action is to reduce speed and alter course *outward*; but if the actual position, B, of the ship is plotted it will be seen that the correct action is a reduction of speed and a slight alteration of course *inward.*

A better understanding of the problem of keeping station on a line of bearing can be gained by working out what will happen if the ship stationed keeps a steady speed, but alters course either inward or outward. The effect of such alterations is shown in fig. 14–3 both for a ship stationed abaft and before the beam of the guide.

A common fault when keeping station on a bearing is to use too large alterations of course. Once the ship is on the correct track it should be possible to keep her there with not more than 2-degree alterations either way.

Open formation

Modern tactics frequently require the adoption of circular and similar formations rather than standard distance and manœuvring interval. Although ships may not be in line, the maintenance of accurate station remains important if the purposes for which the formation is designed are to be fulfilled.

It is essential that the position of own ship, guide and other units should be kept plotted on a manœuvring form or the Fleet Formation Board, not only for convenience in maintaining or changing station, but also in order that alterations of course and changes in the direction of the axis may be executed correctly and at short notice.

ALTERING COURSE

Definitions

A *turn-together* is a manœuvre in which all ships turn simultaneously, thus maintaining their true bearings and distances from the guide. On the other hand, to *wheel* is to alter course in such a manner that on completion of the manœuvre all ships will be in their former relative positions. When wheeling, the *pivot ship* of a line is the wing ship in that line on the side toward which a wheel is being made.

Wheeling when in column

The correct execution of a wheel by a single column depends largely on the station-keeping of ships in column at the time the guide starts to turn. If ships of similar type are in correct line, and put their rudders over at the same point

and on the same heading as did the guide, little difficulty should be experienced in turning in her wake. Ships in column should be steadied by compass on the bearing of the guide at the moment she starts to turn, and each ship should try to get perfectly steady as the turning point is approached. A swing, or large rudder angle either way, upsets the estimation of the right moment to start the turn, and alters the normal turning path of the ship.

The exact moment to put the rudder over may be judged by the position of the *kick* or swirl in the wake made by the rudder of the next ahead, if she is turning correctly in the guide's wake. If the ship ahead is turning badly, one must try to turn in the wake of the guide, provided this can be done without closing the next ahead unduly. The correct position of the kick of the next ahead, relative to own ship's compass platform at the time the order is given to put the rudder over, may be calculated for various speeds of ship. For example, at 15 knots, if the distance from bridge to rudder is 400 ft and the time taken to put the rudder over is 15 seconds, the next ahead's kick should be just abaft the compass platform. (Own ship will travel 375 ft in 15 seconds.) At 30 knots the kick should be 350 ft *before* the compass platform. This method presupposes that the kick does not develop until after the rudder has been put over, which is not strictly the case. It is only by constant practice that the correct moment can be judged under varying conditions.

Another method is by relative bearing of the bridge of the next ahead, or of the guide, calculated for various speeds and positions in the line. These methods are illustrated in fig. 14–4.

A common mistake before the start of a turn is to steady by compass outside the true turning-point. The outward swing of the next ahead's stern, combined with her loss of speed when turning, gives the impression that she is falling across own ship's bows. The natural temptation to steer outside her at this stage must be resisted, as she will soon draw clear, and will remain so during the completion of the turn. The bows must, however, be kept well inside the *wake* of the next ahead, i.e. inside the path traced out by her stern. The bows should, in fact, be kept somewhat inside the middle of her slick.

When completing the turn, especially when ships ahead are turning badly, watch the bearing of the guide and bring the ship on to the correct bearing as she arrives on the signalled course.

No column of ships can wheel satisfactorily unless the leading ship steadies accurately on the new course. She should habitually ease the rudder at the same moment, and meet with about the same amount, so that other ships may learn what to expect. It is imperative that she should not swing past her course and thus ruin a manœuvre otherwise carried out perfectly by the remainder of the column.

If the correct moment to start the turn has been misjudged and the rudder put over too late, more wheel must be used and speed increased. If, despite these measures, the ship turns outside, she will fall astern of station, and it is then important to remember the instruction that the ship must steady outside the track until she can edge into her place at the correct distance. Ships which cannot be relied upon to observe this instruction will be a source of embarrassment to those astern.

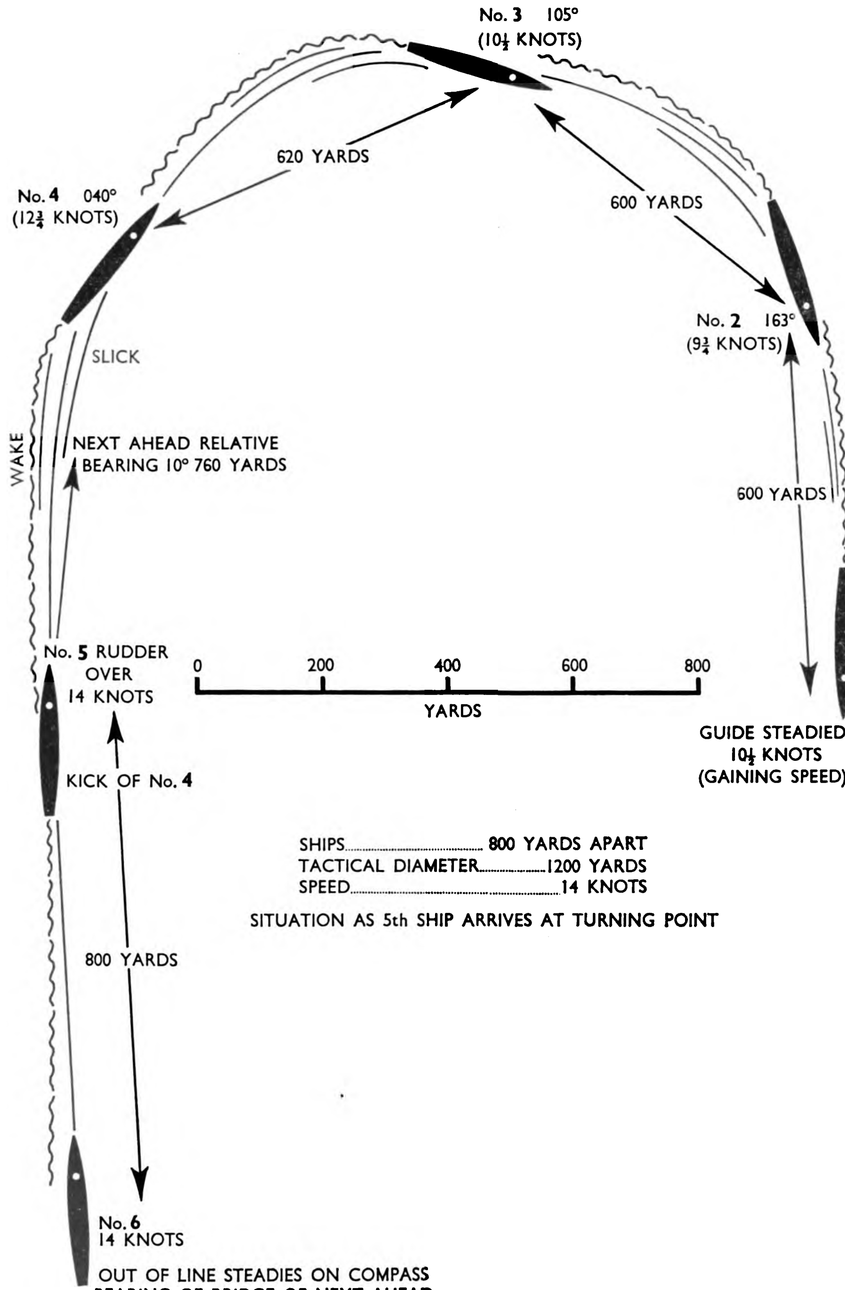


FIG. 14–4. A column of heavy ships altering course 180° by wheeling

Turning too early, and inside, is a fault which can be rectified in the early stages. The rudder should be eased promptly, otherwise in a large turn the ship will soon find herself in an uncomfortable position. It may not be necessary to reduce speed if the rudder is eased as soon as the bow is seen to be drawing across the stern of the next ahead, for the ship will subsequently require to turn in a smaller circle with increased rudder and will lose distance in the process. An unnecessary reduction of speed must inevitably hamper the next astern.

Altering course together

When ships in line turn together any differences in advance and transfer between the ships will make station-keeping difficult during and immediately after the turn. For example, the Officer in Tactical Command may indicate that the tactical diameter to be used is 1,200 yd. At the speed of the fleet the guide's advance for a 90° turn may be 1,000 yd, whereas the remaining ships in the line, using wheel to produce a tactical diameter of 1,200 yd, may advance only 900 yd (fig. 14–5). They must therefore vary their rudder angles as necessary

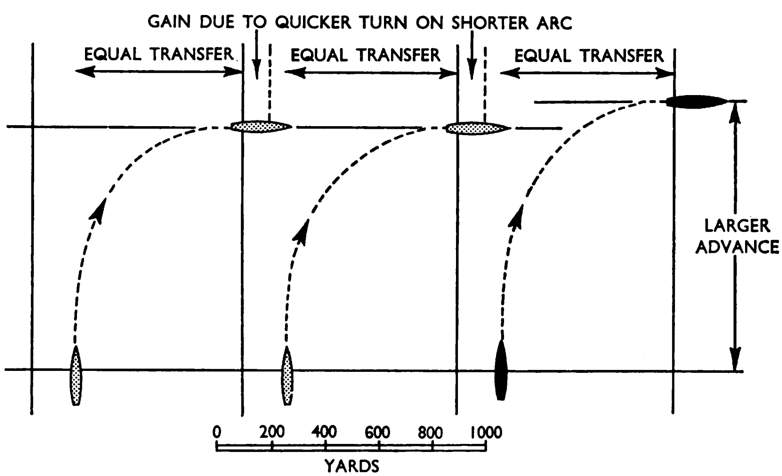


FIG. 14–5. Turning 90° together—effect of variations in advance

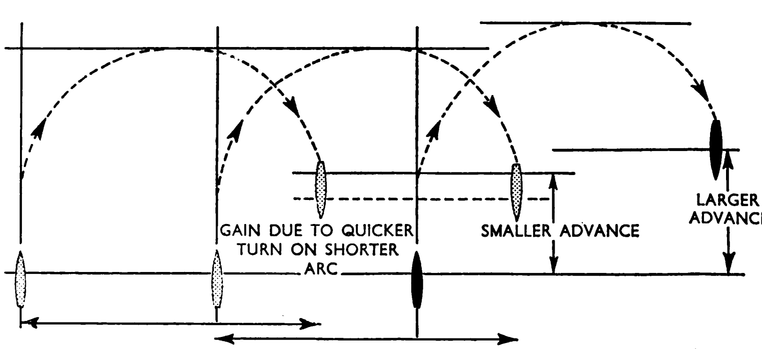


FIG. 14–6. Turning 180° (line abreast)

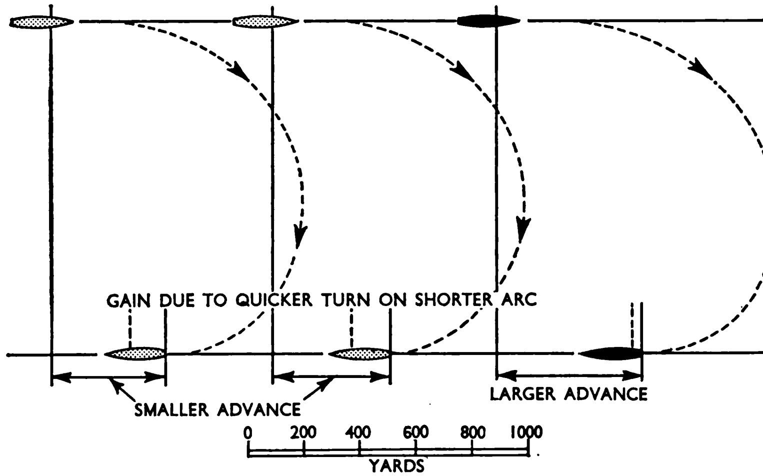


FIG. 14–7. Turning 180° (line ahead)

during the turn. Even when executing a 180° turn-together it is undesirable to use the same wheel throughout the turn if the advance of the guide differs greatly from the remainder, for although ships may complete the turn either in correct line *or* at correct distance, they will not achieve *both* (figs. 14–6 and 14–7).

The remedy in the above cases is to start the turns under small wheel and later increase the rudder angle considerably, though the estimation of the rate at which the guide is turning is by no means easy. Thus, in addition to maintaining the correct bearing and distance throughout the turn, the shiphandler must judge the inclination of the guide and compare it with the heading of his own ship.

TAKING UP AND CHANGING STATION

Speed to be used

The speed to be used in a force by ships changing station is indicated in tactical publications. However, a new station should always be taken up promptly unless the O.T.C. indicates to the contrary by giving a definite time at which the ship is to be in station, or otherwise controls the action to be taken.

Gaining ground

In Chapter 12 it was shown (page 274) how to use a standard allowance of a number of yards per knot when accelerating or decelerating, but the shiphandler was warned not to expect great accuracy from the method, and he must be prepared to adjust speed as necessary during the course of a manœuvre. Common practice is to allow 100 yd per knot for a heavy ship and 50 yd per knot for a frigate or destroyer.

For example, suppose a frigate is approaching the fleet from astern at 20 knots and is ordered to take station 3 cables astern of another ship proceeding at 12 knots. At what distance astern of the other ship should the frigate reduce

speed to 12 knots? Allowing 50 yd per knot, the frigate should reduce to 12 knots at $[(20-12)\times 50]+600=1{,}000$ yd.

Acceleration and deceleration tables

Instead of allowing ships to accelerate and decelerate at rates governed by the engine-room staff in each ship, the O.T.C. may order standard rates for his force and promulgate these in tables. In practice, however, it is unlikely that in a force consisting of large and small ships the latter will be able to keep to the standard rate by engine-room action alone, and it will be necessary for the Officer of the Watch to vary his revolution orders during changes of speed in order to keep station accurately on the heavy ships.

Losing ground

When a ship is required to take up a new station that is practically astern of her, there are three possible ways of doing so, assuming that the guide continues on her present course:

1. If there is only a short distance to drop, she may reduce speed and then increase again, using any available data on deceleration and acceleration.
2. If time permits she may turn through 180°, and then continue the turn right round through a full 360° at the appropriate moment. The time taken to turn through 360° at various speeds can be obtained from Turning Trials results. To

Typical cruiser using 25° rudder

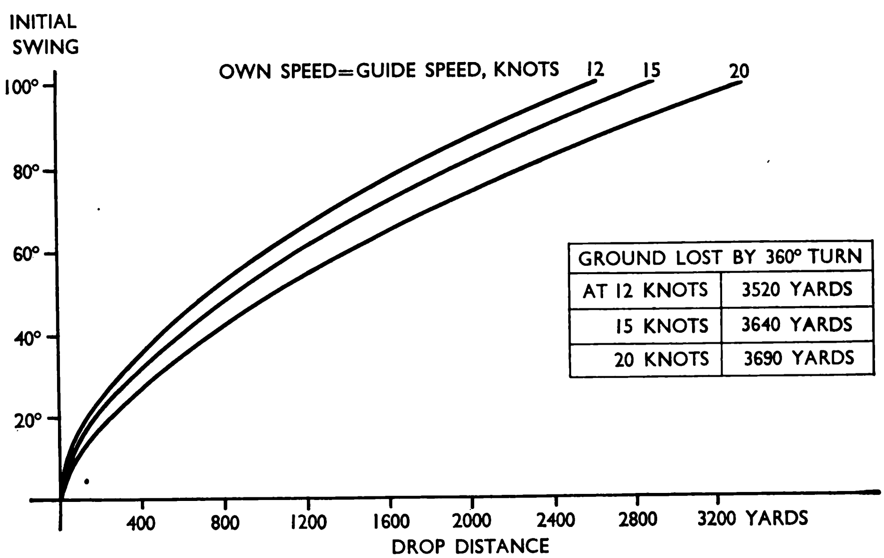


FIG. 14–8. Graph showing how to drop distance by zigzag for a particular class of cruiser. This operation consisted of an initial swing out, followed by a swing of twice the amount back, and then a final alteration to the original course. A period of 30 seconds on a steady course between turns was allowed. The speeds of the unit and the guide were assumed to be equal and constant throughout

find how far the ship will drop distance on the guide by a 360° turn, the advance for this turn, the time required to regain the speed lost during the turn, and the distance travelled by the guide during the manœuvre must all be considered. It is helpful to construct a table showing how much ground will be lost by the ship doing a 360° turn for various speeds of guide. When the new station is ordered one can then see at a glance if there is time to turn through 360° without finishing up astern of the new station.

3. If there is insufficient time to turn through 360° the ship may drop distance by making a broad zigzag. This is a smarter and more rapid method than by a reduction of speed, and in war it enables the ship to maintain a better defensive capability against surprise air or submarine attack. The method is sometimes known as making a 'fishtail'. The ship puts on, say, 25° of wheel and swings either to starboard or port, reversing the wheel so that the ship's head reaches a certain angle from the original course (say, 60°) and then keeping on the reversed wheel so as to bring her back to her original course. A graph of this initial swing (e.g. 60°) against the drop distance obtained for various speeds of guide may be drawn, after plotting out the track of the ship from Turning Trials data (fig. 14–8). In the example in the figure the manœuvre included a period of 30 seconds steady on the outward course. However, such a graph can give only a rough approximation of the distance lost, because the precise behaviour of the ship when turning is influenced by the prevailing weather, etc. and cannot be deduced exactly from the Turning Trials data. The manœuvre can be carried out only if there is sufficient room laterally to starboard or port to do it without inconveniencing other ships.

Taking station from a position ahead or on the bow

The situation given under (2) above must be elaborated when there is time to turn right round and proceed towards the new station. As the ship proceeds on a nearly opposite course towards the unit to be stationed on, it will require fine judgment to estimate the point at which to put the wheel over to turn into the new station. If the ship is stationed several miles ahead or on the bow of the guide there may be time to work out this point by calculation and plotting, but such methods must be used in conjunction with a trained eye, which can be developed only by practice. Various quick methods of doing the calculation from previously prepared data and tables and by using radar, etc. exist, and some of these are given in *Admiralty Manual of Navigation*, Vol. I, while others are described below. First, consider what must be done if the calculation has to be done from first principles during an actual manœuvre. The factors to be taken account of in the calculation are:

1. the time taken to turn from the approach course to the guide's course, and the distance travelled by the guide during this period,
2. the advance and transfer during this turn,
3. the speed lost during this turn,
4. the allowance of a safety margin in case of miscalculation.

Plotting the turning-point is simpler if the approach is made on the reciprocal of the guide's course, but the principles are exactly the same if approach is from the bow, so an example of the latter is given.

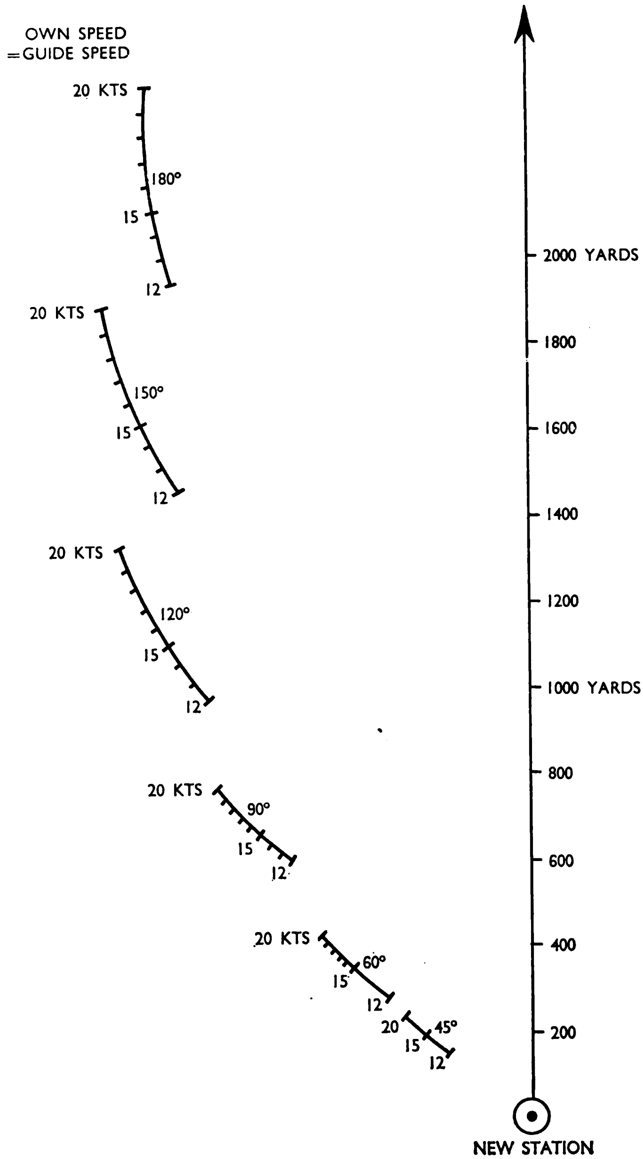


FIG. 14–9. Data for estimating the turning-point when taking station from the bow, as plotted on a tracing of a mooring board. The position of the guide must be plotted relative to the new station, and a safety distance allowed when turning into column. (Based on typical figures for a cruiser)

In fig. 14–10 the guide (X) is steering 340° at 14 knots. Own ship (A), stationed 5 miles bearing 300° from the guide, is ordered to take station in column 800 yards astern of her. Speed available is 20 knots.

1. A first plots the course to intercept the guide at 20 knots and alters to it (095°), increasing to 20 knots.
2. Next he plots a safety distance (say, a quarter to one-third of the tactical diameter of his final turn) laterally—BC in fig. 14–11 (300 yd). He now proceeds to find the point at which to turn so as to finish up in position C.

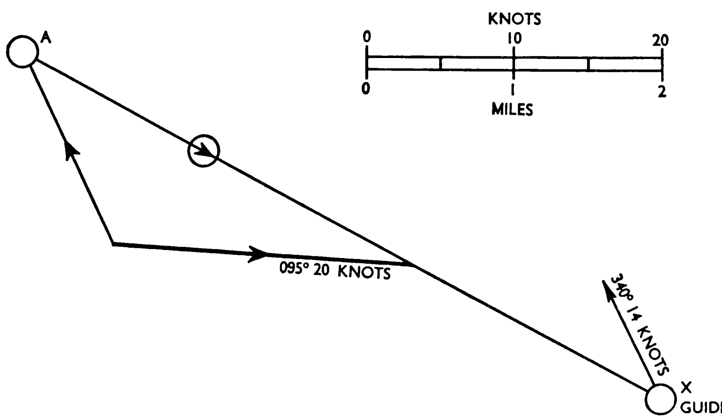


FIG. 14–10. Example of taking station from a position on the bow—first estimation of approach course

3. He decides to take the estimate for the amount of his final turn into column as 120°, for which he has advance and transfer data in his Turning Trials reports (the assumption in this case being that he will approach the turning-point on a course of 100°).
4. The final turn is now plotted back from C, assuming that it will be made at 14 knots. CD, the transfer for a 120° turn at 14 knots using, say, 15° of wheel, is plotted at right angles to the final assumed approach course of 100°—that is, in this case, in a direction 190° from C.
5. The corresponding advance is plotted back D to E along the final assumed approach course of 100°.
6. To allow for loss of speed during the turn the distance EF is plotted back along the guide's course from E. This is the *distance correction* for a 120° turn at 14 knots. (The method of obtaining distance corrections is given in *Admiralty Manual of Navigation*, Vol. I.)
7. The distance FG steamed by the guide during the turn is then laid off in the direction the guide is steaming.
8. G gives the point at which to put the wheel over, in this case when the guide bears 100° distant 1730 yd.

The distance correction EF can be neglected by making the final turn at a speed greater than the guide's speed by an amount equal to A's loss of speed

during the turn (e.g. at, say, 17 knots in this case) and then reducing to the guide's speed just before arrival in station.

If during the final turn it is seen that the ship is certainly going to attain the intended final position C, the wheel can be eased as necessary and revolutions adjusted so as to edge in to the line and complete the manœuvre in the proper station B. On the other hand, if the ship has made a bad shot the safety distance BC should at least keep her clear of the column, even if ahead or astern of her intended station.

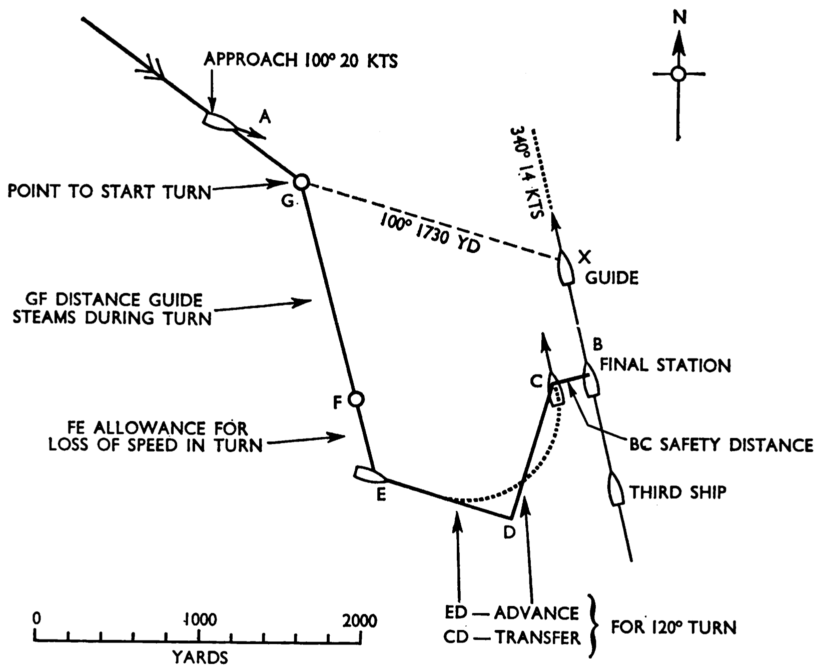


FIG. 14–11. Calculation of turning-point (G) when taking station from a position on the bow of the guide

In the example it is found that by adjusting the initial course from 095° to 100° the ship should pass through point G. If a much larger adjustment had been required it might have been necessary (time permitting) to make a second approximation. However, the calculation may take at least five minutes, by which time the shiphandler in A will have covered half the distance to the turning-point without being able to take his eyes from his plotting. A more rapid method of finding the turning-point is clearly desirable.

The essential feature of the manœuvre is that the ship should pass *exactly* through the pre-determined turning-point on *approximately* the course for which that turning-point has been calculated. An error of a few degrees in the amount of final turn will make little difference to the advance and transfer. On the other hand, if the ship, even though on the correct approach course, starts to turn, say, 100 yd from the intended turning-point, then she will obviously finish up about 100 yd from her intended station.

Quick methods of plotting the turning-point

By plotting out in advance a number of turns for different speeds, and amounts of final turn, a table such as that shown below can be prepared. Normally the safety distance is not allowed for in the table and must be plotted separately. The table gives the relative bearing and distance of the turning-point from the new station. This must first be plotted, and then the true bearing and distance of the guide from the turning-point obtained.

TAKING STATION FROM THE BOW IN A CRUISER USING 25° WHEEL

Table gives relative bearing and distance in yards of turning-point from new station.

Guide Speed = Own Speed	Final Alteration of Course					
	180°	150°	120°	90°	60°	45°
(Knots) 10	24° 2000	29° 1600	38° 1160	41° 760	50° 360	50° 200
12	23° 2080	29° 1660	38° 1200	42° 800	50° 420	50° 240
14	22° 2200	28° 1760	37° 1300	42° 860	49° 460	50° 300
16	22° 2320	27° 1860	37° 1400	42° 920	49° 520	51° 340
18	21° 2420	27° 2000	36° 1480	42° 960	48° 560	51° 360
20	20° 2520	27° 2100	35° 1600	42° 1000	48° 600	51° 380

NOTE: A safety distance should be applied when turning into column.

An alternative method is to plot the data (on the same scale as a mooring board) on a tracing (fig. 14–9). This tracing can be aligned with the position and course of the guide on a mooring board, and the appropriate turning-point pricked through.

Reversing the order of ships in column

A description of this manœuvre when carried out from rest is given on page 351. If carried out at sea, the manœuvre takes longer to complete and more sea room is required. When a column is ordered to reverse order of ships in column in succession from the rear, the rear ship automatically becomes guide and increases to one knot less than stationing speed, passing the ships ahead of her on the side indicated. Other ships reduce to 7 knots or as indicated. At the appropriate time each ship in succession from the rear increases speed and takes station in the wake of the ship that was next astern of her previously.

It is difficult to estimate exactly the time and sea room that will be required to complete the manœuvre. Basically the need is for the *time* occupied by the rear ship in traversing twice the length of the column at a relative speed equal to the difference between 7 knots and a speed of one knot less than stationing speed. The *distance* required ahead of the rear ship is that traversed by the rear ship during this time at one knot less than stationing speed. However, a little reflection will reveal that account must be taken of acceleration and deceleration in the various ships in the column. For example, the leading ship does not at once drop to her new speed of 7 knots, and may not in fact reach it before it is time for her to accelerate again.

A formula that gives an *approximate* time for the manœuvre is

$$T=\frac{[2L+2\ (S\times C)]\times 60}{S\times 2000}\ \text{minutes}$$

where S=difference in speeds in knots between one-knot-less-than-stationing and 7, or between the two speeds ordered;
L=length of the line in yards;
C=correction in yards per knot, for gain and loss of speed for the class of ship concerned.

For example, a column of four ships steaming at 12 knots is ordered to invert the line. Stationing speed is 20 knots and ships are 800 yd apart. Yards-per-knot correction is 50.

$$T=\frac{[2\times 2400+2\ (12\times 50)]\times 60}{12\times 2000}\ \text{minutes,}$$

$$=15\ \text{minutes.}$$

In 15 minutes the rear ship will cover $4\frac{3}{4}$ miles at 19 knots. Thus a distance of 3·55 miles is required ahead of the original guide in order to complete the manœuvre. However, since the formula can give only an approximate time, it would be wise to add at least 25 per cent to the calculated distance ahead of the original guide, and for example call it in this case $5\frac{1}{2}$ miles. Remember that at the end of the manœuvre all ships will be proceeding at one knot less than stationing speed and, if it is then necessary to reduce speed, time will be required to signal the new speed and reduce to it.

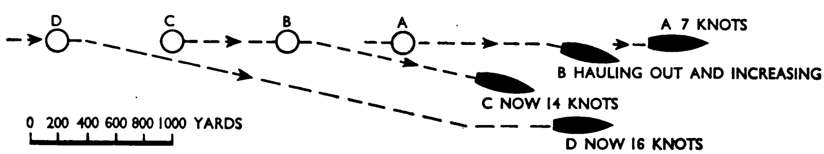


FIG. 14–12. Example of reversing order of ships in column. Initial speed was 12 knots, final speed 17 knots. Typical situation of four heavy ships after 7 minutes, showing need for new guide to haul well clear of column

During the manœuvre each ship must judge the moment to increase speed so as to fall into correct station on the new guide, observing that her own speed and that of the ship being stationed on may be anywhere between 7 knots and one-knot-less-than-stationing at the time. In fig. 14–12 it will be seen that ship C will probably require to increase before D draws abeam. Ships A and B should therefore base their timing on the new guide D rather than on the ship due to be next ahead after the manœuvre. It is clear from the figure that the new guide should haul well out to allow for the fact that several ships may be very nearly abreast one another at some stage.

LEAVING HARBOUR IN COMPANY

Unmooring

When ships are moored it is arranged as a rule that the berths are far enough apart to allow any ship to unmoor independently whatever the direction of wind

or stream. But, even so, if all the ships unmoor together it will be necessary for adjacent ships to take care not to hinder one another. If, for example, ships of a column are lying in line with their anchors and one ship weighs her lee anchor more quickly than her next ahead, she should delay shortening-in on her weather cable until her next ahead has also weighed her lee anchor.

Suppose there are two lines of ships moored, as in fig. 14–13, with the cables laid out along the lines. Each ship has 5 shackles or 450 ft of cable on each anchor,

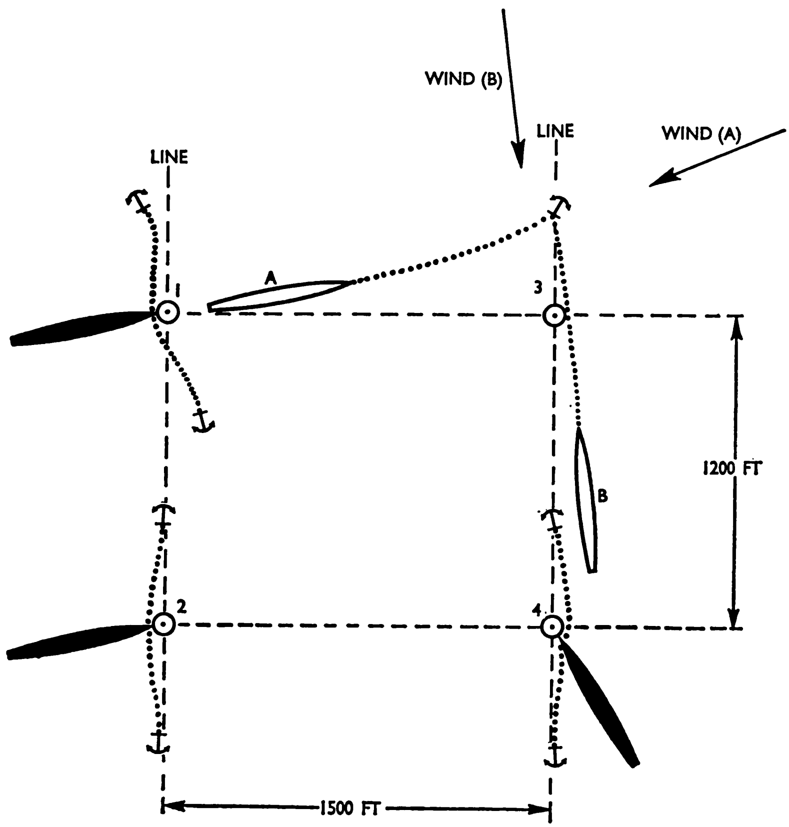


FIG. 14–13. The distance to allow between lines of ships moored, and between berths in the same line, depends on the need for any ship to be able to unmoor independently, whatever the direction of wind or stream

so that there will be about 825 ft between a ship's anchors. Considering a ship A unmooring independently in the windward line (from berth 3 in fig. 14–13), it is clear that the distance to the opposite berth in the leeward line (1) must allow of her swinging nearly to the full scope of her weather cable as soon as her lee anchor has been weighed. Thus the lines should be spaced apart at least by this scope (825 ft) plus the length of the ship. Assuming all ships are of one class each 600 ft long, the distance between lines should be at least 1425 ft (say, 2½ cables).

On the other hand, if the wind is blowing not across the lines but along their

length, a ship B unmooring independently from berth 3 in fig. 14–13, when lying at the full scope of her weather cable, need not have quite so much room between her berth and that of the next berth to leeward. This is because her cable extends from a point further to windward than was the case with ship A. Theoretically, the minimum distance between berths in the same line would be *half* a span of cable (in this case, 450 ft) plus the length of the ship (600 ft), which would give 1050 ft or $1\frac{3}{4}$ cables. However, a safety margin should be allowed, and a reasonable distance for this class would be 2 cables (1200 ft).

The basic problem of swinging room when moored is outlined in Chapter 13.

Weighing

When ships of a unit in separate berths have weighed together, or slipped from buoys together, they preserve the same bearing and distance from the senior officer of their unit as existed before getting under way, until further orders are received. The senior officer may then order them to cast to port or to starboard or to a particular course. While doing so they should not gather headway or sternway, and they should endeavour to turn at the same rate as the senior officer.

Inverting column when leaving harbour

If the senior officer led his squadron into harbour he will probably order his column to invert the line when leaving. In these circumstances it is preferable to turn at rest together to a heading that is 20° short of the course for leaving

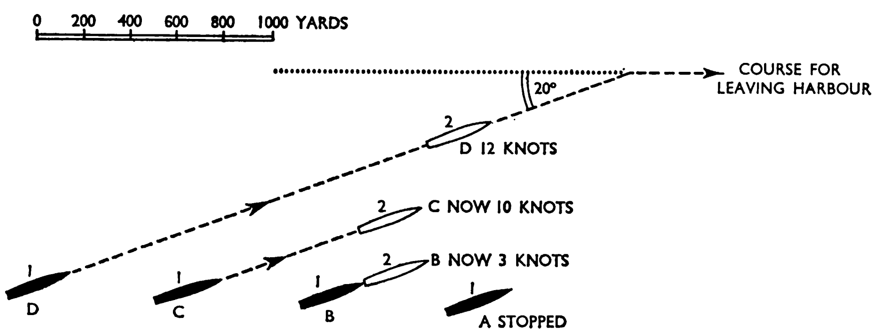


FIG. 14–14. Four ships—A, B, C and D—inverting the line from rest on leaving harbour. Positions 2 show the situation after 8 minutes if speed ordered is 12 knots

harbour, so that each ship, when her turn comes, can go ahead into clear water without having first to turn to avoid her next ahead (fig. 14–14). Each ship must determine the correct moment to go ahead so as to take station in the column. If ships in the column are of the same class it is a fairly simple matter to calculate this moment as occurring at a certain time interval after the moment at which the senior officer, or ship to be next ahead, has put her engines ahead. The method is based on the assumption that each ship puts her engines to half-speed ahead at the revolutions for the speed ordered in one movement at the calculated moment.

Consider ships C and D in fig. 14–15. C's problem is to let D gain station-keeping distance (say, 3 cables), plus the distance CD measured at the time D was seen to go ahead. Assuming this total to be 6½ cables and the speed ordered to be 12 knots, then if the ships are of the same class they can be assumed to accelerate at the same rate, and the time interval required is simply the time D takes to cover 6½ cables at 12 knots. In this case this is 3¼ minutes, and if C goes ahead at 12 knots 3¼ minutes after D is seen to go ahead she should fall into correct station.

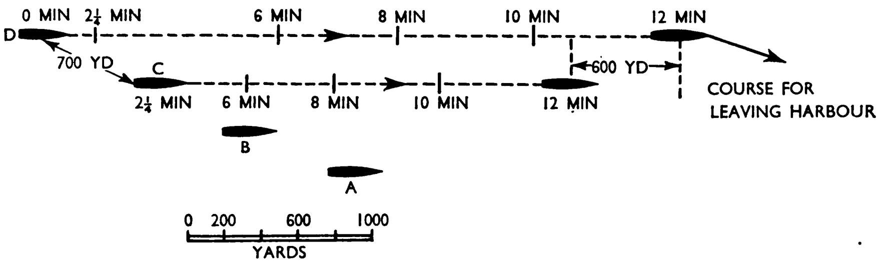


FIG. 14–15. Inverting line from rest—determination of correct moment to go ahead to take up station

If ships are of dissimilar class and the ship taking station has a slower rate of acceleration she must obviously go ahead sooner (and vice versa). A simple approximation is to reduce (or increase) the time interval by an amount depending on the difference in the yards-per-knot acceleration figure for the two ships. For example, if D's figure is 50 yd per knot and C's is 100 yd per knot (in fig. 14–15), correct the distance to be covered by D (that is, 6½ cables) by subtracting $12 \times (100-50)$ yd.

The corrected figure is $(6\frac{1}{2} \times 200) - [12 \times (100-50)]$ yd
$= 700$ yd, or 3½ cables.

The corrected time interval is that required by D to cover 3½ cables at 12 knots, that is, 1¾ minutes.

When the manœuvre is being done by ships of slow acceleration the situation is similar to that described above when reversing the order of ships in column at sea. Several miles of sea room will be required to complete the manœuvre.

If ships go ahead prematurely they will find themselves bunched up or even abreast of one another when they have attained the speed ordered. One should therefore resist the temptation to start going slow ahead before the time interval has elapsed. On the other hand, the speed ordered for the manœuvre should be such that ships have a reserve of speed available with which to catch up smartly if they find they have gone ahead too late.

ANCHORING IN COMPANY

Anchoring in formation

There are two ways of anchoring a unit as a whole. Either the anchors of all ships are let go simultaneously, in which case the senior officer makes use of a signal meaning 'Anchor instantly'; or the senior officer leads the unit into

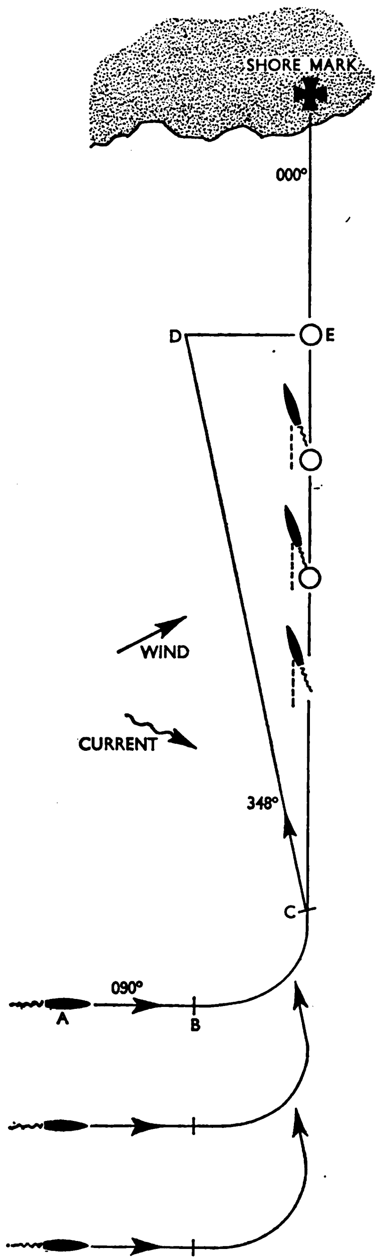


FIG. 14–16. Anchoring a column in a cross wind or current

harbour so formed and disposed that each ship will pass through her allotted berth, and then orders ship to anchor 'in accordance with previous instructions' as convenient when approaching the berths.

In both methods, but particularly in the former, it is most important for all ships to maintain station accurately. In the first method ships must maintain exact station until the moment of letting go; while, in the second, ships maintain station as far as is practicable up to the moment of anchoring, but are at liberty to steer for their assigned berths as soon as the appropriate signal is executed. The guide must be particularly careful to keep a steady course and speed, and must not make any changes in either without signal. Ships should always be ready to anchor individually if ordered, and the navigating officer should see that the necessary bearings have been laid off and noted to enable this to be done.

Anchoring a column in a cross current or wind

An example of a method of conducting a column to its anchor berths in a cross wind and/or current is shown in fig. 14–16. The guide (A) approaches steering 090° with ships on a line of bearing 180°, which is the line of the anchor berths. It is estimated that between the turn to the anchoring course and the arrival in the berths the wind and current will set the unit three cables to leeward, after considering that during this period speed must be reduced first and engines stopped later. A position D is therefore plotted three cables to windward of the guide's berth, and the unit is turned together on to the anchoring line CE, but steering a course of 348°.

If the estimate has been accurate, ships will find themselves slightly to windward of the anchoring line on stopping engines, but as their speed through the water falls they should drift on to the correct line by the time the signal to anchor is executed. If the guide does not proceed accurately along the first approach course AB, the estimate for point D will be in error and should be adjusted.

It is essential to choose a good shore mark ahead so that it is easy to see which way the ships are being set when on the anchoring course. If it is uncertain which way the ships will be set the senior officer may make two signals, one ordering a turn-together of, say, 10° to port and the other of 10° to starboard. He may then execute either one of the signals during the approach, if necessary; or he may find that he needs to execute one, followed after an interval by the other. He will thus have ready a quick means of adjusting course either way during the final approach. If it is not essential for the ships to anchor exactly in the allotted berths, the senior officer may prefer to sacrifice accuracy of berthing position in order to maintain accuracy of station, and if so will not order any alterations of course during the last mile.

CHAPTER 15

Handling Ships in Heavy Weather

GENERAL CONSIDERATIONS

Avoidance of damage

How best to handle a ship in heavy weather depends so much upon the type, size and capabilities of the particular ship that it would be unwise to lay down precise instructions as to how to act in various circumstances. A seaman studies carefully the reactions of his ship in heavy seas and thereby gains a sympathetic understanding of her sea-keeping qualities. He learns how she should be handled, and how far she can be pushed, without incurring danger or damage.

Often in a warship the need to carry out the assigned task conflicts with the need to avoid weather damage, but it never makes sense to drive a ship in a storm in such a way that she sustains damage to the hull or is placed in danger of foundering. The fact that a modern warship has powerful engines means that in rough weather she not only has the means to extricate herself from danger, but also the means to inflict great damage upon herself. A good seaman does not regard serious weather damage as an unavoidable misfortune, let alone an honourable wound, but rather as being as culpable as any other damage resulting from careless shiphandling. Superficial damage caused in heavy weather to boats, davits, guard-rail and awning stanchions, hatches, etc. may have to be accepted for operational reasons, but can usually be avoided without affecting the achievement of the ship's task.

It is important to record in the Navigational Data Book and in the Ship's Book information about how the ship has behaved on particular occasions in heavy weather, and any useful advice based on these experiences. A new captain, on joining his ship, should be able to find some valuable knowledge there.

A force commander is responsible for the safety of ships under his command, but he is often in a big ship and may not realise fully how the weather is affecting conditions in the small ships. It is the duty of individual captains of small ships to signal the force commander if they expect damage to be caused by maintaining course and speed, particularly at night.

Knowledge of the stability of his ship and of the various steps that can be taken to improve it is essential to the seaman if he wishes to preserve her safety in heavy weather. Stability of ships is described in Vol. II, Chapter 1, and also in Chapter 1 of this volume.

Precautions

Before leaving harbour the ship should be fully prepared for sea, as described in Vol. II, and this work must include the proper securing of everything that is movable, particularly if it is evident that heavy seas will be met as soon as the harbour entrance is passed.

Steps to increase the stability of the ship must be taken in ample time before the weather deteriorates. Such steps include pumping, flooding or ballasting,

and jettisoning deck cargo, and it is clear that they must be done while the ship is still fairly steady; otherwise they may endanger her during the adjustment of stability by creating free-surface effects of liquids or off-centre loadings.

Consideration of the crew

In heavy weather the Captain and the Officer of the Watch must constantly keep in mind the effects of the motion of the ship upon the members of the ship's company as they go about their various duties. Violent motion may reduce the efficiency of, or slow down, certain operations, such as those concerned with the control of engines or weapons. Seasickness may affect inexperienced men. On exposed decks jackstays should be rigged to help men move forward or aft.

Broadcast the intention to alter course in heavy weather a few minutes before doing so. Men will then be prepared for the new kind of motion; this applies particularly to turning beam-on to a swell. If possible, avoid making alterations of course during meal hours.

When men are working on the forecastle speed must be reduced to a point at which there is no danger of the ship dipping her bows under. On leaving harbour when a long swell is met but the wind is light, those on the bridge may be deceived as to the amount the ship is likely to pitch. Remember that one green sea over the forecastle may sweep men overboard, and that lives have been lost in the past through such lack of foresight.

SEA AND SWELL WAVES

Characteristics of waves in the sea

The formation and action of waves at sea is discussed in some detail in *Admiralty Manual of Navigation*, Vol. III. The following are some of the more important facts which emerge:

1. The particles of water in an unbroken wave do not move along with the wave, but oscillate within quite narrow limits, moving upwards as the crest approaches, forwards as the crest passes, downwards as it recedes, and backwards almost to their original positions as the trough passes.
2. Both the length and steepness of waves increase with wind speed, but when the wind rises above 10 knots the rate of increase of height becomes much greater than that of length. No individual wave can, however, attain steepness of more than that which corresponds to a height-length ratio of about 1 in 10 without breaking at the crest.
3. A group of waves moves at only half the speed of the individual waves forming the group. Consequently the same wave does not remain the highest of a group, but waves passing through a group attain their maximum height at the centre. 'White horses' do not, therefore, remain on the same waves, and in a simple wave formation a wave only foams at the crest when passing near the centre of a group. In a cross sea, which is the rule rather than the exception, waves will, however, break more frequently. In deep water, the water forming the broken crest of a wave may be considered as moving forward and downward at about half the speed of the wave.

4. In the most general terms, the fact that a wave attains its maximum height when passing near the centre of a group accounts for the familiar periodic appearance of an extra large wave. The combination of two or more wave patterns similarly results in a fairly regular recurrence of groups of large and small waves, with occasional periods of comparative calm. The number of waves in each group and the interval between successive appearances of extra high groups vary with the type of sea.

An unbroken wave is far less dangerous than a breaking wave. In the former the movement of water is mainly up and down, there being comparatively little forward or backward movement: but in the latter a great mass of water is

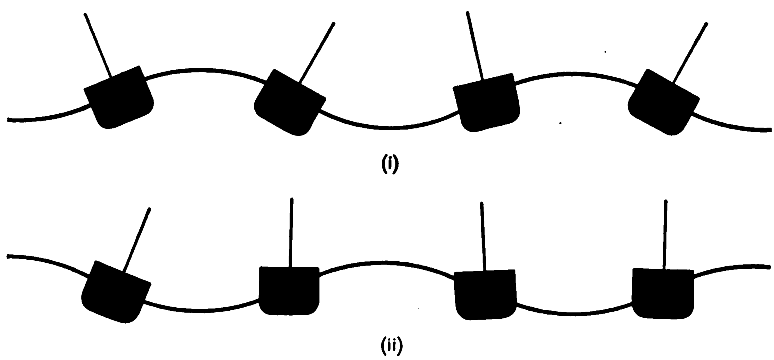


FIG. 15–1. Effect of the waves on the motion of a ship

projected with considerable force forward and downward from the crest; furthermore, a naturally breaking wave is higher and steeper than its unbroken counterpart. An unbroken wave can, however, be broken by impact with the ship, and its potential danger is then nearly as great as the wave which has broken naturally.

Waves running from deep to comparatively shallow water grow steeper and higher and then break up and subsequently re-form into a short, steep sea with breaking waves. If the extent of the shoal water is limited by land a backwash is set up which results in a confused sea with dangerously steep and breaking waves.

A heavy swell caused by a strong and prolonged gale over a large expanse of deep water may travel hundreds of miles without appreciably altering its direction. If it meets seas from a different direction caused by a local gale a dangerously confused sea will result.

Broadly speaking, a short steep sea, or a confused sea, is more dangerous to small vessels than to large ships; and conversely, a long, heavy sea is more dangerous to large ships than to small vessels.

Effects of wave motion on a ship

All ships have a natural period of roll and pitch according to their dimensions and conditions of loading.

The *period of roll* is the time a ship takes to roll from one side to the other and back again.

The *period of pitch* is the time the bows of a ship take to rise from the horizontal, fall below the horizontal and return to it.

The *period of encounter* is the time interval between the passage of two successive wave crests past any given point in the ship.

The movement of a ship in roll or pitch depends on the size of the waves and the relation between the period of encounter and the ship's period of roll or pitch, the greatest movement developing when there is synchronisation. The period of encounter depends on the wave length (which governs the wave speed) and also on the course and speed of the ship relative to the waves. Thus the period of encounter can be varied by alteration of the ship's course and speed.

When the period of the ship is small in comparison with the period of encounter she will tend to ride the waves, keeping her deck parallel to their slope (fig. 15–1(i)). In a beam sea this will result in rapid, heavy rolling. In a head sea a small period of pitch should result in an easy motion, without much water being shipped.

When the period of the ship is large in comparison with the period of encounter she will roll or pitch independently of the waves. In a beam sea this should mean a comparatively easy motion, though waves slapping against the weather side may make her wet (fig. 15–1 (ii)). In a head sea a comparatively long period of pitch may result in occasional burying of the bows and exposure of propellers and rudder.

When the period of encounter approaches synchronisation with the period of roll or pitch, the ship's motion will be violent. In a beam sea this may result in dangerously heavy rolling, while in a head sea the severe and rapid pitching movement may cause frequent racing of propellers and unfair hogging and sagging strains.

For a large ship, such as a carrier, the natural period of roll is about 14–15 seconds; for a cruiser, 11 seconds; and for a frigate, 8 seconds. Periods of pitch are about half those of roll. As already stated, the period of encounter depends on the size and direction of the waves as well as those of the ship, but the following figures, which relate to ships heading into waves of their own length, may be helpful.

	Period of encounter at ship speed of: 15 knots	20 knots
	sec.	sec.
Carrier (say, 720 ft long)	8·4	7·6
Cruiser (sa,y 550 ft long)	7·1	6·3
Frigate (say, 360 ft long)	5·3	4·7

An important effect of wave motion on a ship is the loss of stability she suffers as she rides over the crest of a wave. In a ship with a low reserve of stability this may result in a dangerous increase of roll or list, particularly in a high beam wind.

HEAVY ROLLING—CAUSES AND REMEDIES

Factors contributing to heavy rolling

Light draught. Though a warship is not subject to the great variations in draught of a cargo ship, the effect of expenditure of fuel and ammunition on the propensity to roll may be appreciable. Although the inconvenience of cleaning

salt water out of flooded fuel tanks is considerable, flooding may occasionally be necessary to avoid weather damage due to excessive rolling.

Free water. The free movement of water from one side of the ship to the other—whether in flooded compartments, below the centre of gravity, or on deck—will increase the period and degree of roll. This effect will be most marked when the free water is high in the ship, e.g. in bulwarked ships with inadequate or inefficient freeing ports. In ships with continuous bulwarks or well decks, such as small escort vessels and tugs, the correct functioning of freeing ports is essential to stability in rough weather.

Snow and ice. A considerable coating of snow and ice on rigging, superstructure or on deck will obviously affect the stability of a ship adversely, but to an extent which may not be generally appreciated. For instance, a deposit of six inches of loosely-packed snow on the flight deck of a large aircraft carrier can add a topweight of as much as 100 tons, while a coating of two inches of frozen spray over the exposed area of a cruiser's upperworks may amount to 30 tons or more. When de-icing is impracticable, allowance must be made for the modified sea-keeping qualities of ships in such conditions. For methods of dealing with ice coating see Chapter 17.

Anti-rolling devices

Bilge keels are the simplest and most common form of anti-rolling device, and are fitted in the great majority of H.M. ships. They are built approximately perpendicular to the hull, at or near the turn of the bilge, and are usually continuous over about half the length of the ship. In general, bilge keels materially decrease the amplitude of roll and slightly increase the period. Their effectiveness increases with the forward speed of the ship, and largely for this reason a ship will usually roll most heavily when stopped and drifting in a beam sea.

Gyroscopic stabilisers have been fitted in some merchant ships and yachts. They are an effective form of stabiliser, but have the disadvantages of great weight and, so far as warships are concerned, the vulnerability of the heavy rotating element.

Fin stabilisers are fitted in a number of H.M. ships. In this system, in its most simplified form, retractable rudder-type fins project almost horizontally through the side of the ship at points near the turn of the bilge on each side. The angle of incidence of the fins to the flow of water past the ship is varied automatically as the ship rolls, the leading edges of the fins on the side which is moving down being turned up, and vice versa. The disadvantage of this system of stabilisation, apart from its complexity and weight, is that the effectiveness of the fins depends on the ship's forward speed through the water, and that their operation involves a small, though appreciable, loss of speed.

Anti-rolling tanks, which reduce the amplitude of roll by varying the amount of water in tanks on opposite sides of the ship, are fitted to some ships. An improved design, occupying less space than former ones, has been tried in ships of the U.S. Navy and is claimed to be successful.

EFFECT OF WIND ON A SHIP

Once a ship has been obliged to reduce to slow speed in a storm the pressure of the wind on her hull will have an increased effect on her handling qualities. The effect is enhanced if the ship is lightly laden, or is of shallow draught, or has large superstructures. When going very slowly or when stopped, most ships tend to lie broadside-on to the wind, and in exceptionally strong winds it may be difficult to turn them up into the wind, though it may be possible to turn them away downwind. In a typhoon or hurricane it may be impossible to turn certain ships into the wind, which is one good reason why any seaman avoids such conditions with land or dangers to leeward.

Leeway caused by the wind

The amount of leeway a ship makes in a gale depends on her speed, draught and freeboard, and on her course in relation to the direction of the wind and seas. In winds of gale or hurricane force the leeway with the wind abeam can be very considerable, and may amount to as much as two knots or more, particularly if the ship is steaming at slow speed.

It is a common mistake among inexperienced seamen to make insufficient allowance for leeway, particularly in a prolonged gale when, in addition to the wind, there will be a surface current caused by it. The amount of leeway made by a ship in various circumstances can only be judged by experience, but it is wise to allow a liberal margin of safety when passing dangers to leeward, because cases abound of ships having gone aground through failure to make sufficient allowance for leeway in the course steered.

HANDLING A SHIP IN A SEAWAY

Steaming head to sea

There are three factors to be considered when a ship is heading into a seaway, namely: the force of impact of the waves on her bows; the pitching of the ship and the resultant strains of hogging, sagging and pounding; and waves breaking on board, whether this is caused by their impact with the hull or the pitching of the ship, or both.

The force of impact of the waves varies with the product of the ship's mass and the square of the combined velocity of the ship and the waves, and a small reduction of speed will therefore considerably lessen the force of impact. The larger the area offered to the seas the greater will be the shock of impact, and when ships whose bows are considerably flared, such as aircraft carriers, are pitching, they will be forced to reduce speed sooner than ships with comparatively straight-sided bows. Smaller ships such as frigates and destroyers are liable to incur damage through bumping if driven too fast into head seas; but these ships are designed today with more emphasis on ability to keep up a good speed in heavy weather, and they have higher and longer forecastles than former designs.

The trim of a ship may have a considerable effect on her behaviour when steaming into a head sea. If she is trimmed at all by the head, or if she is heavily

laden forward, she will probably pitch sluggishly and tend to bury her bows in the waves. Conversely, if she is trimmed too much by the stern her bows will tend to pay off to one side or the other, and it will be difficult to keep her on her course heading into the seas. The best condition for a ship steaming into a head sea is for her to be trimmed slightly by the stern and lightly laden forward, thus ensuring that her propellers and rudder are well immersed and that her bows are buoyant.

An alteration of speed may have a considerable effect on the pitching of a ship because it alters the period of encounter, but a reduction of speed does not necessarily reduce pitching, nor does an increase of speed necessarily increase pitching. After a reduction of speed on account of the weather the heavy ships of a fleet are sometimes more uncomfortable and ship more water than do their smaller consorts, and in such circumstances it may be best for the heavy ships to continue at their original speed but to zig-zag, so as to maintain the same speed over the ground as their consorts. In a short head sea it may be possible to increase speed to a point at which the period of encounter is considerably reduced and the ship rides comfortably over the waves at relatively high speed with little pitching. Ordering a large speed increase with this result in view is, however, a difficult decision to make. If the outcome has been misjudged the ship may sustain damage through bumping, either while attempting the increase or while reducing speed if the attempt is abandoned.

Pitching can sometimes be lessened by altering course so as to bring the seas on the bow, but the resulting motion with both pitch and roll may be more uncomfortable and more water may be shipped. Such action may prove essential, however, in order to prevent the stern being continually lifted out of the water, so causing the propellers to race, thus straining the propeller shafts and bearings and the blades of the propellers.

Steaming with the sea abeam

The rolling caused by a beam sea may be so excessive that men have difficulty in keeping their feet, let alone in carrying on with their work efficiently, particularly in a small ship. The best way to reduce the rolling is to alter course so as to prevent the ship's rolling period from being synchronous with the period of encounter. Alterations of speed are unlikely to affect the amount of rolling at all. Ships seldom incur damage to the hull through rolling, but superficial damage to boats or that caused by seas breaking on to low decks, such as the quarterdeck, may occur. Objects may break loose if they have not been properly secured.

Running before the sea

Running before the sea carries with it certain dangers, but these can usually be avoided by altering the speed and hence the period of encounter. The dangers consist of *broaching-to* or being *pooped* and arise in the following way: If the ship's length is comparable to, and her speed practically the same as, those of the waves, she may find herself running for a considerable time on the crest of a wave. The stern is high in the water, and the control by the rudder becomes less effective. If she now pitches on to the forward slope of the wave and the wave breaks, the entire ship will be carried forward with the breaking water and she

begins to plane along with the wave, or, to use an easily-understood expression, she starts *surfing*. The forward motion of the water relative to the rudder and propellers further diminishes steering control, and a yaw either to starboard or port may develop rapidly and may be quite impossible to correct. The bow now buries itself deep into the trough and the stern is swung round until the ship lies broadside to the waves. This is the process called *broaching-to*. She now begins to roll heavily, and if a following wave breaks upon her in such a way as to reinforce her roll to leeward, she may be heeled further over and capsize. These stages are shown in simplified form in fig. 15–2.

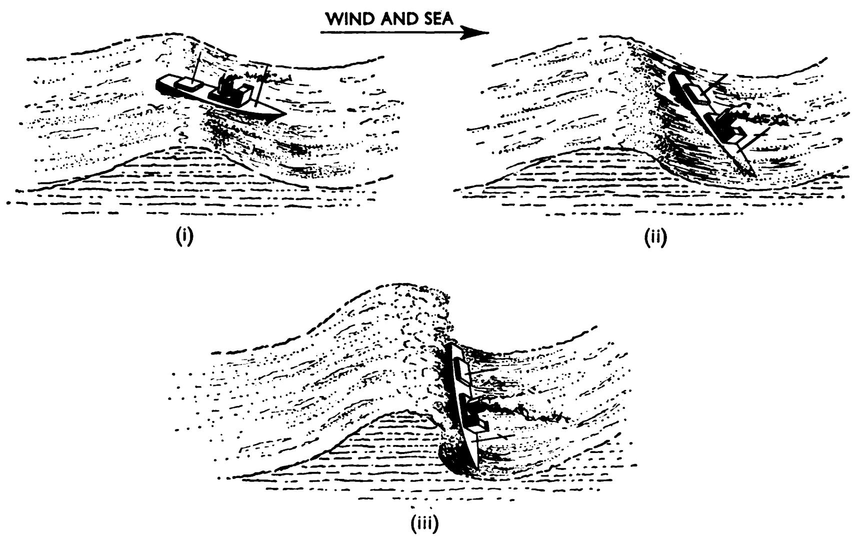


FIG. 15–2. Stages in a vessel being broached-to

If the ship is on the forward slope of a wave that breaks upon her, the water may sweep along her upper decks from aft, causing damage. She is then said to be *pooped* (fig. 15–3). A ship may be pooped without having lost steerage control, and usually when going slower than the speed of the waves.

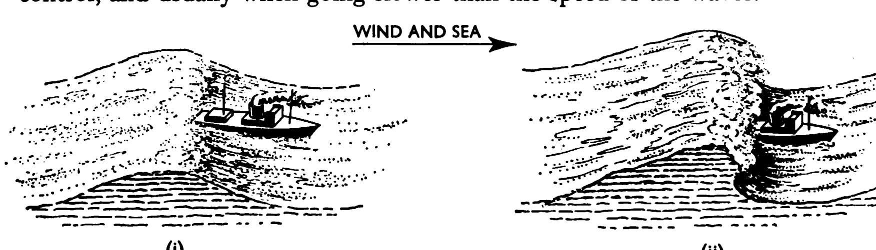


FIG. 15–3. Stages in a vessel being pooped

Of these dangers it is of paramount importance to avoid surfing and being broached-to, and this can be done invariably by reducing the speed of the ship to well *below* that of the waves. To be safe, ship speed should be at least 40 per cent below wave speed. For instance, a ship at 20 knots can start surfing on a wave whose speed is 26 knots. A ship may still be pooped if a very heavy sea breaks

aboard, and the steering will probably be difficult; but many ships have reported that better control is possible and damage can be more easily avoided by steaming downwind in heavy seas than by attempting to keep head to sea. This applies particularly during replenishment-at-sea operations (see Chapter 16).

To keep the ship well below the wave speed should not be difficult in a big ship, because waves of 600 ft or more in length usually have a speed of at least 30 knots. Waves of 300 ft and less may be travelling at under 15 knots, and in these circumstances small ships such as destroyers and frigates must watch their speed carefully in a heavy following sea.

If running before the sea towards an estuary or towards shallower water, remember that the waves will become higher and steeper, increasing the danger of broaching-to and adding to it the danger of yawing right out of the navigable channel into shoal water. An attempt to increase speed above the wave speed will involve a period of lack of steering control while the ship's and waves' speeds coincide, and is in these circumstances foolhardy.

The possibility of being broached-to or pooped decreases greatly if the length of the waves is either much greater or much smaller than that of the ship. Steering before a heavy sea is, however, always liable to be difficult, and allowance must be made for a certain degree of inevitable yawing on either side of the intended course. Constant supervision of the steering by the Officer of the Watch and a reduction of the length of tricks at the wheel will be required.

To avoid being blown along at the speed of the waves small vessels may stream a drogue to reduce their speed and avoid the dangers of surfing.

Turning in a heavy sea

There may be considerable risk in attempting to turn a ship about in a heavy sea, and good judgment is required in selecting the most suitable moment to start the turn.

If head to sea and one wishes to turn and run before it, the risk of damage will be greatest probably half-way through the turn, when the sea comes abeam. At that moment also the ship will be most reluctant to turn. It has already been mentioned that groups of relatively low waves alternate with groups of higher ones, and therefore one should try to get the ship round so that she is beam-on to the sea during one of the calmer periods. During the first part of the turn one must avoid gathering much headway, because this may cause heavy pitching. Short bursts of ahead power against a fully-angled rudder, possibly combined with reversals of the inner screw, should get the ship half-way round. From there the turn should be completed as rapidly as possible, using full power for a short time on both screws if necessary.

In a following sea, speed should be reduced as far as practicable before starting the turn. Never go so far as to gather sternway into a heavy sea, however, for the impact of the waves on the rudder and propellers may damage them severely, leaving the ship helpless. Again, if possible, choose a relatively calm period to start the turn and, having got half-way round—which should not be difficult—use plenty of power and full rudder to start the ship turning into the wind. As soon as she starts to answer her wheel, reduce the speed of the engines to the minimum judged necessary to turn her head to wind and keep her there.

HEAVING-TO

The weather may become so violent in the open sea that the performance of the current task, whether it be a passage from one place to another, or some operation, must be subordinated to the overriding need to steer and handle the ship in the best possible way to avoid damage and to keep her afloat. The course and speed previously ordered are abandoned and the ship is *hove-to.* There are, broadly speaking, three ways of heaving-to, the aim in each case being to keep the ship as steady as possible and to prevent seas breaking on board and damaging or flooding her, and, in the last resort, to prevent the ship foundering through flooding or capsizing. The three methods are:

1. lying with the sea on the bow and steaming ahead at the minimum speed consistent with steerage way,
2. lying with the sea on the quarter and steaming ahead at the minimum speed consistent with steerage way,
3. stopping engines and allowing the ship to drift.

Method 1. Sea on the bow

The decision to adopt this method may be forced on the captain because of lack of sea room to leeward. To keep her bows up the ship will require revolutions for a speed of anything from, say, 6 to 12 knots, but she may make little headway and may even lose ground to leeward. If she has a reasonably long and high forecastle the ship may be protected to a certain extent from seas breaking over her decks. The disadvantage of the method is that the engines are being used to drive the ship against the sea, and hence to increase its power to damage her. Heavy pitching and pounding may occur, even if the revolutions are reduced to the minimum needed to keep steerage way. In a ship with a wide, flared bow, such as an aircraft carrier, the risk of incurring structural damage forward will be great.

A single-screw ship may find it easier to keep the ship's head up with the wind fine on the port, rather than the starboard bow, because of the sideways force of the propeller.

Method 2. Sea on the quarter

This method can be adopted provided there is plenty of sea room to leeward. Certain ships may prove drier and more comfortable in this attitude, but the speed must be adjusted to avoid broaching-to or being pooped and the steering must be carefully supervised. All ships will find that steering is difficult downwind, and some may be quite unmanageable.

Method 3. Drifting with engines stopped

Again, if this method is adopted there must be plenty of room to leeward for the ship to drift. Not only will the wind and breaking seas carry the ship to leeward, but the wind will set up a surface current. The rate of drift in winds of gale force may reach 2 or 3 knots, and at hurricane force it may even reach 5 knots.

It has been argued that if a ship approaches near the centre of a tropical storm, this method of heaving-to is the only logical one to adopt, because, the sea being confused and not coming from any particular direction, it is impossible

to place the ship either head to sea or stern to sea. The use of the engines is likely at one moment to push the ship into a huge wave and possibly drive her forecastle under, or at the least to cause damage; while at the next moment she may force herself down the crest of a wave approaching from astern and broach-to.

Authentic cases have been reported in recent years of ships successfully riding through, or very near to, the centre of typhoons in the Pacific with engines stopped. In these cases the ships have sustained no damage whatsoever, although both pitching and rolling have been heavy. The ships reported on had in each case adequate stability (i.e. metacentric height) and good watertight integrity. When near the centre of the typhoon, the ships lay with the wind approximately abeam, but the waves approached from all directions.

Method to adopt

Having considered the above remarks, the captain, knowing his own ship and her stability and handling qualities, forecasting the future trend of the weather and considering the sea room available, must decide for himself which is the best method to adopt in the prevailing circumstances.

The following factual cases may be of interest:

1. 'An aircraft carrier and her attendant destroyer were hove-to in the Bay of Biscay in a storm and in a very high, steep and confused sea. The carrier steamed at revolutions for seven knots with the sea on her bow, pumping oil on the water for the sake of the destroyer, which kept station about two cables on the carrier's lee quarter. At the height of the storm the carrier was pitching and pounding heavily, with seas breaking over her flight deck; but the destroyer, of some 900 tons, was riding quite comfortably and drily, heaving up and down like a cork. Sixty miles away a large, well-found freighter foundered with all hands when lying in the trough of the waves after her engines had broken down.'
2. 'Two cargo liners of the same class, on the same route and owned by the same company, were overtaken in the Bay of Biscay by particularly bad weather. The engines of one broke down and she drifted helplessly beam to sea in the trough of the waves, but she rode out the gale safely, her engines were repaired and she continued her voyage. Her sister ship some miles away foundered at the height of the storm when hove-to steaming slowly head to sea.'
3. 'In a destroyer of 1,500 tons that operated in many Atlantic gales the following general rules were found useful:
   a. The ship could run comfortably before the sea at a speed of from ten to twelve knots, but at a higher speed there was a tendency to broach-to. When running, she rode best with the sea slightly on one quarter.
   b. When running before a gale the height of the swell was carefully noted, and when it appeared to be higher than the bridge it was usually advisable and more comfortable to turn and heave-to with the wind about 20° on the bow. After turning, the engine revolutions were kept at a speed corresponding to about nine knots, the speed being increased temporarily if the ship showed a tendency to fall off her course. When hove-to at nine knots the ship did not pound too badly, and steerage way could usually be maintained.'

AVOIDANCE OF TROPICAL REVOLVING STORMS

Whenever possible the seaman should give a wide berth to a hurricane, cyclone or typhoon, because these revolving storms, especially their centres, are so violent that small ships may well founder in them and large ships be seriously damaged. Action to avoid such storms should be taken in good time, because once the wind and sea start to rise they usually increase so rapidly that the ship may soon become unmanageable and unable to steer a course for safety. The methods of foretelling the advent of a tropical storm and of determining its probable position and course, and the rules for avoiding it, are to be found in the first part of each volume of the *Admiralty Sailing Directions*, or in *The Mariners' Handbook* (S.D. 100), and these should be studied by every seaman.

SEA ANCHORS

Much has been written about the effectiveness of sea anchors in keeping a vessel head to wind and sea and reducing her rate of drift to leeward, but most of this advice was given in the days of sail when vessels were equipped with heavy wooden spars and stout canvas sails which were eminently suitable for making a sea anchor of effective size. It is doubtful whether a sea anchor of sufficient size to hold any but very small vessels can be constructed with the materials available in the average steamship of today.

USE OF OIL TO CALM THE SEA

Oil spread in small quantities on the surface of the sea will prevent the waves breaking and damp down the effect of the wind in whipping up the waves into sharp crests. It will not, however, reduce a swell, and its value lies in lessening the probability of shipping water in a heavy, breaking sea. Good results can be obtained from any type of oil, but animal or vegetable oils are more effective than mineral oils, and heavy oils are better than light oils. In cold weather the oil should be warmed to decrease its viscosity. The methods of spreading the oil, either through scuppers or soil-pipes or by means of oil-bags or canvas hoses, are described in Chapter 6. The following brief rules should serve as a guide to determine the most effective way of distributing the oil in certain circumstances:

When *running before the sea*, distribute the oil from the bows by means of oil-bags or through the forward soil-pipes. The oil thus spreads aft and gives protection from seas from right astern and from the quarter. If it is only distributed from the stern there will be no protection from quartering seas. If yawing badly, distribute the oil from the bows and from both sides amidships. If it is only distributed from the bows the weather quarter is left unprotected when the ship yaws.

Oil will probably be ineffective if the ship is going at more than about four knots through the water.

When *heading into the sea*, the oil should be distributed from as far forward as possible on both sides. Oil-bags slung over the bows will probably be tossed back on deck by the waves, but it is possible to overcome the difficulty by rigging

a spar as a bowsprit and running out an oil-bag to its end by means of a messenger.

When *steaming with the wind and sea abeam*, the oil should be distributed through soil-pipes and scuppers from the weather bow and the weather side amidships.

When *hove-to bow to sea, or drifting with the wind and sea abeam*, the oil should be distributed through soil-pipes and scuppers, or by oil-bags spaced at intervals of 40 to 50 ft along the weather side.

When *at anchor*, the oil should be distributed from oil-bags hauled out ahead of the ship by means of a messenger rove through a tail-block hitched to the cable.

GENERAL ADVICE ON HEAVY WEATHER AT SEA

From the information given so far in this chapter the reader will realise that no hard-and-fast rules can be laid down on handling a ship in heavy weather at sea. It depends on the type of ship and her handling qualities, the wind and sea, the room available and other circumstances. Unfortunately, experience shows that there are few generalisations about the behaviour of ships in heavy seas that hold good in all similar circumstances. Cases are on record that show that while the handling of a certain ship in a certain way has proved successful in one instance, yet in another similar one it has apparently led to a ship's foundering. However, it must be emphasised that the design of Her Majesty's ships always embodies a good margin of safety in stability, and that by following generally the advice given above damage can usually—and disaster can always—be avoided. Perhaps it may be helpful to summarise this advice in a series of 'do's' and 'don't's'.

DO

1. Make sure that you are kept informed continually about expected changes of weather.
2. Know the factors affecting the stability of your ship and take steps to improve stability, if necessary, *before* encountering heavy weather. (See Chapter 1 and also the chapter on *Elementary Stability* in Vol. II.)
3. See that the ship is made thoroughly seaworthy before leaving harbour, or before the approach of a storm.
4. Consider the effect of the ship's motion on the activities being carried out by all the various members of the ship's company.
5. Appreciate the signs of an approaching tropical storm and take the necessary action to avoid it. (Full information is given in *Admiralty Sailing Directions* and in B.R.45(2), *Admiralty Manual of Navigation*, Vol. II.)
6. Alter course, if possible, in a beam sea to break the synchronisation of the period of the waves with that of the ship's rolling.

DON'T

1. Drive a ship too fast into a head sea—particularly a fast, lightly-built ship such as a frigate or destroyer.

2. Fail to reduce speed soon enough in a head sea or swell through being unable to visualise the consequences, or fear of being considered too cautious.
3. Run too fast before a following sea, particularly when the length of the ship and that of the sea are about the same.

HEAVY WEATHER IN HARBOUR

Anchoring in a gale

If it is expected that the ship will have to ride out a strong and prolonged gale, it is best to use both anchors and to let them go in such a way that when the ship is riding to the cables the angle between them will be about 20°. To do this the approach should be made with the wind a little before the beam (fig. 15–4 (1)) and the weather anchor should be let go first, with headway on the ship. The ship should then be brought to rest when about a third of the amount of cable

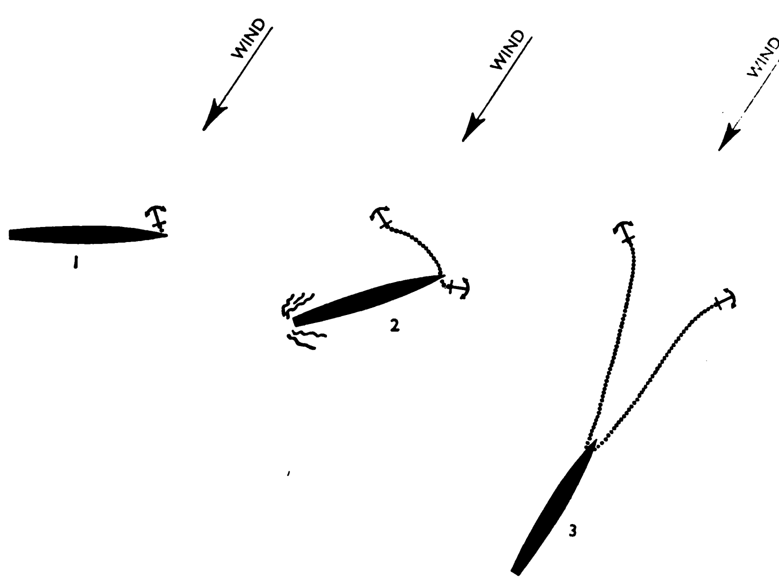


FIG. 15–4. Putting down two anchors in a gale

intended to be veered eventually has run out (fig. 15–4(2)). At this point the lee anchor is let go and, with the ship now swinging head to wind and drifting to leeward, both cables are veered and middled at the intended amount (fig. 15–4 (3)). While this method of anchoring does make use of the maximum holding power of the two anchors, it also carries with it the danger of getting the cables crossed if the wind shifts direction considerably.

Steaming into the bight of the cables

Having anchored as above in a gale with both anchors down and the cables fully veered and spread about 20° apart, it may happen that despite these precautions the ship starts to drag because of the excessive strength of the wind. A useful expedient in such a case is to steam up to windward between the anchors until the cables are growing aft on either quarter and then to hold the ship there with the engines going slow ahead. Further dragging is prevented and with the constricting effect of the cables it is a fairly simple matter to keep the ship stationary and head to wind until the weather moderates. While doing so, one should take the precaution of fixing the ship's position frequently.

A single-screw ship was anchored with both anchors down in the path of a hurricane. When the wind reached hurricane force she found it was no longer possible to steam up head to wind, and the anchors started to drag. She then found that by going astern the port quarter was canted up into the wind. The cables now grew out on the port beam with no undue weight on them, and dragging ceased.

When at single anchor in a gale

If suddenly overtaken by a gale when at single anchor the first precaution to take is to veer enough cable to ensure that the stresses of yawing or pitching are absorbed as much as possible by the spring in the cable, and that the cable is exerting a horizontal pull on the anchor. At the same time steam should be raised, an anchor watch set, and the second anchor prepared for letting go.

Even in a very steady gale a ship will not always point dead into wind, and

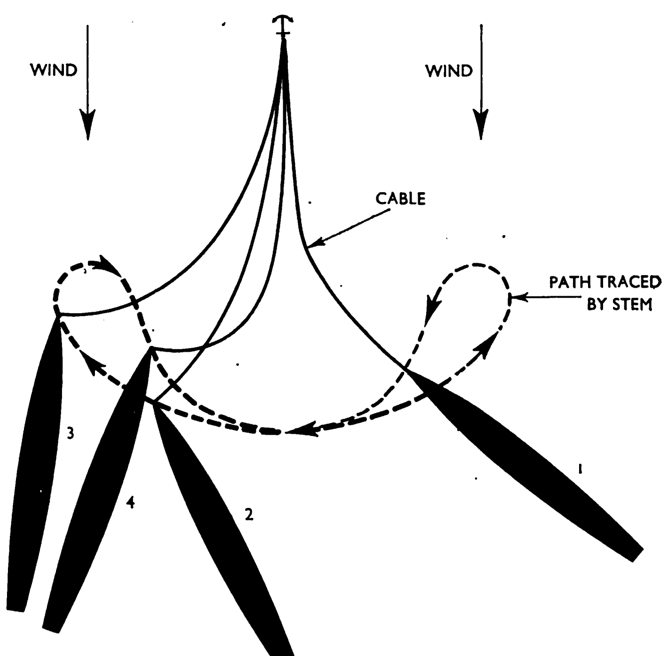


FIG. 15–5. A ship at single anchor in a strong wind

yawing is started by the wind blowing on one side of the ship when she is not heading into wind, so causing her to sail through the water. The combined actions of the wind and the pull of her cable will make the ship yaw first to one side and then to the other, her stem tracing a figure-of-eight path, as shown in fig. 15–5. From this illustration it will be seen that the ship presents a large windage area throughout the greater part of the yaw, thus increasing the strain on the cable. Furthermore, an extra heavy load is imposed as the ship rides up on her cable and then falls back at the extremities of her yaw. Ships with their superstructure disposed forward and with a deeper draught aft than forward are more prone to yawing than ships with their superstructure amidships or aft and trimmed on an even keel. Yawing to any marked degree may cause the anchor to drag, and it should therefore be prevented when practicable.

Opinion differs among experienced seamen on the best method to check a yaw. Some let go the second anchor underfoot at the middle of the yaw and hold it at short stay, so that the pull of the anchor as it drags along the bottom helps to check the yaw. Others let it go when the ship reaches the limit of her yaw to that side which is farthest from the first anchor. They then veer both cables until the second anchor has sufficient cable to enable it to hold, and the ship then rides to both her anchors. If circumstances allow, however, and if there is a probability of dragging, it is best to steam ahead to a position close abreast the first anchor, drop the second anchor, and then ride to both cables veered an equal amount.

Weighing a single anchor in a gale

If the anchor is being weighed because the ship is dragging in a gale, the anchor may begin to come home well before it is weighed and the ship to drift rapidly to leeward. The engines should then be put ahead boldly and the ship steamed to windward, towing her anchor along the bottom until she is in a position to weigh it, then to anchor again or proceed to sea.

When dragging at single anchor *beam-on* to a strong gale it may be difficult to get the ship head to wind to weigh it. In these circumstances, if sea-room allows, the engines should be put ahead and the ship steamed round her anchor. The drag of the anchor on her bow should bring the ship up into the wind, when she can steam to windward of her anchor and then drift down on it while weighing. In ships with high bows and their superstructure disposed well forward this method may prove impracticable, and the only alternative is to attempt the same manœuvre but by going astern instead of ahead, relying on the tendency of all ships to bore up stern to wind when moving astern.

Weighing both anchors in a gale

If both anchors are down in a gale, either the cables should be middled with a fair amount out on each, or one of the anchors should be underfoot. The anchor underfoot can be weighed without difficulty, and this should be done as soon as the wind moderates or begins to back or veer, so as to avoid getting the two cables foul of one another.

If the cables are middled the best method is to heave in both cables together so that both anchors will be weighed simultaneously. If the cables have originally been spanned at 20° this should present no difficulty, and if the ship has dragged

so far as to draw both cables together into alignment with the wind, this method will still give the best chance of getting them both up without fouling one another. Thus, if the amounts out on each cable are not equal, it will probably pay to middle the cables first before starting to heave them in together.

Emergency action

If a gale warning is received when in an anchorage where the holding-ground is none too good, where there is little sea room to leeward, or where other ships are berthed nearby, it is best to weigh and anchor again with both anchors in a clear berth well upwind, or if this is impracticable to proceed to sea.

If at anchor in a gale, it may be impossible to weigh because of lack of sea room to leeward with the ship already dragging, and the only safe course in this case may be to slip the cable or cables and proceed to sea. When slipping a cable, the end should be buoyed to enable it and the anchor to be recovered subsequently, the wire-rope buoy pendant used being of sufficient strength to recover the cable.

Approach of a tropical revolving storm

If warning of a typhoon or a hurricane is received when the ship is in harbour, the decision whether to ride it out or put to sea depends largely on the type of ship, the nature of the holding-ground or strength of the moorings, what sea room is available, and the proximity of the storm and its probable course. If it is decided to put to sea the decision must be made in good time so that the ship may make a good offing and so have plenty of sea room to leeward when the storm overtakes her. It is often inadvisable to put to sea when the storm arrives, because when the ship leaves the shelter of the harbour she may meet mountainous and confused seas set up by the backwash from the coast.

Ships secured to buoys have successfully ridden out a typhoon by steaming to their bridles, thus easing the strain on both bridle and mooring. The position of the buoy being fixed and well in sight from the bridge or forecastle, there should be no danger of overriding the bridles or getting out of position, but one must try to keep a steady strain on the bridles and not to jerk them.

Provided there is plenty of sea room to leeward and the ship is not moving into any dangers or into very deep water, dragging in itself does not always call for drastic emergency action such as slipping the cables. Ships anchored in wide bays or open anchorages have dragged slowly and steadily for several days at the rate of about a mile a day without harm while riding out a prolonged gale. Dragging should, however, be avoided because it imposes heavy loads on the cables as the ship rides up and then falls back on them. A method of preventing dragging by steaming up into the bight of the cable is described on page 368.

Leaving a head buoy in a gale

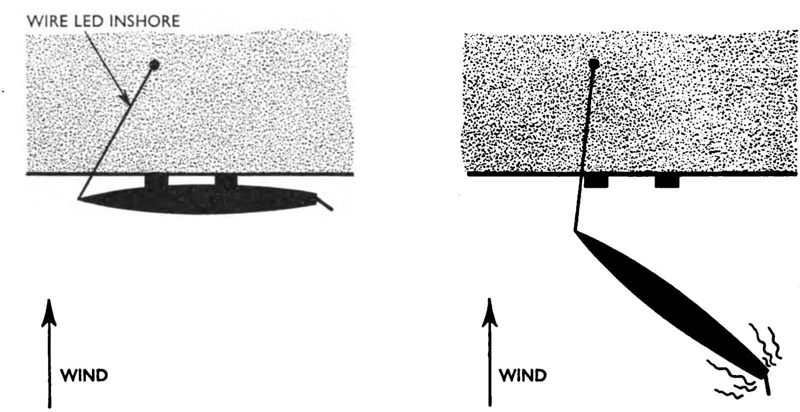
If buoy work is impossible, the cables must be broken on deck and the bridles slipped. When one anchor is catted the work of uncatting should be progressed as far as possible before slipping, so that anchor and cable may be secured before reaching the open sea. The strain on the buoy mooring is likely to be such that the buoy will spring back well clear of the ship on slipping, so that there will be no difficulty in avoiding it if the engines are put ahead at once.

Leaving head and stern buoys in a gale

When it is practicable to slip the stern wires and swing to the bow buoy the problem is simple, but in harbours where head and stern moorings are provided it is unlikely that there will be much swinging room. There may also be occasions when it is possible to slip the bow buoy and swing to the stern buoy before proceeding, but more often, when the wind is broad on the beam or abaft the beam, it will be preferable to slip both buoys simultaneously. Every precaution must be taken to ensure that there is no delay at either end, and that the propellers are not fouled by the stern wires or slip rope.

Leaving an alongside berth in a gale

The most difficult situation will be when the wind is blowing on to the jetty. Although tugs may succeed in hauling the ship clear, she will not be able to move ahead or astern so long as they are pulling, for fear of girding them. The essence of the problem therefore is that the ship should be hauled sufficiently



(i) Go astern (ii) Slip wire

FIG. 15–6. Method of getting a small ship away from a jetty with the wind blowing on

clear to ensure that she does not drift back on to the jetty during the period when she is slipping the tugs and gathering way. If a fore spring proves ineffective, a small ship may be able to cast her stern well out by running a wire from right forward to a point well inside the jetty. When the engines are moved astern, the bows will be hauled into the jetty and the ship will pivot on them as she tries to align herself with the pull of the wire. She will gather sternway more rapidly on slipping than she would do if a fore spring had been used, and she is therefore less liable to scrape her bows heavily on the jetty before getting clear (fig. 15–6). When an anchor has been let go in the process of berthing, the manœuvre is considerably simplified, but even so the assistance of a tug is essential if the wind is of gale force.

CHAPTER 16

Handling Ships while Replenishing at Sea

A description of the methods and gear used for replenishment at sea is given in Volume II. This chapter deals with the problem of how to handle the ship during the process. Normally the supplying ship maintains a steady course and speed. The receiving ship approaches her and keeps station either *close aboard*—that is, with the two ships steaming abreast one another at distances ranging from, say, 50 to 150 ft—or alternatively close astern. In neither case are towing or breast lines used, and station is kept entirely by the handling of the ships. The stores, ammunition, oil fuel or personnel are passed from the supplying to the receiving ship by means of special rigs which are slung between the two ships if they are close aboard, or towed in the water if the receiving ship is astern. Thus the shiphandling problem is essentially one of approaching to a very close distance on another ship, keeping station there if necessary for a period that may extend over an hour, and then of disengaging.

The differences in water pressure round a moving ship produce forces of attraction and repulsion between two ships steaming close aboard, or approaching this position, and these forces are generally referred to as *interaction* between ships. These forces must be understood and allowed for if collision during replenishment at sea is to be avoided. This chapter deals first with the problem of interaction, then with shiphandling during replenishment both abeam and astern, and finally with the use of liferafts for transferring men or stores in heavy weather.

INTERACTION

Some seamen are inclined to consider the difficulties arising from interaction as overstressed. Those with successful experience of handling ships when close aboard are naturally inclined to minimise the difficulties. Interaction can and does exist, however, and disregard of it has caused accidents. Its effects are stronger in shallow water and ships should be on the lookout for it at normal replenishment speeds if the depth is less than 15 fathoms; and if replenishing at 15 knots or more they should expect greatly increased interaction in depths up to 20 fathoms.

Theory of interaction

The pressure in the water round a ship when under way is very different from the pressure when the ship is at rest. It can be shown from hydrodynamic theory that the pressure is increased near the bow, reduced over the midships portion and increased again at the stern. The three main pressure regions are indicated in fig. 16–1.

Lines known as stream-lines are also shown in this diagram. In considering stream-lines it is convenient to regard the moving body as at rest and the water as flowing past it. The stream-lines denote the path of individual particles of water, those passing near the body being diverted by it into curved paths. The

quantity of water flowing between each consecutive pair of lines is the same, so that when the stream-lines are close together the cross-sectional area is reduced and the speed of flow is increased. Similarly, when the stream-lines are spread out the speed is reduced. The particles of water can only move more quickly

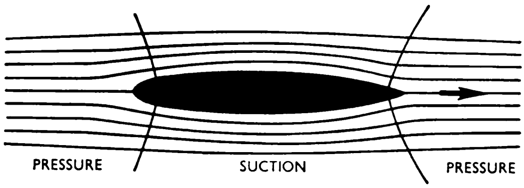


FIG. 16–1. Regions of increased and reduced water pressure round a ship under way at sea

by impetus from high pressure into low pressure, and conversely. Thus whenever the speed is greater the pressure is reduced, and vice versa. In the case of one body only, the pressure and velocity are the same on each side and there is no resultant force acting sideways. If there are two bodies close together the map of the stream-lines is altered, as in fig. 16–2. Amidships the streams are crowded together. The velocity is increased and the pressure reduced so that there is an attraction or suction between two bodies. At the bow and at the stern the stream-line spacing is greater. The velocity is reduced and the pressure increased, so that there is a repulsive force.

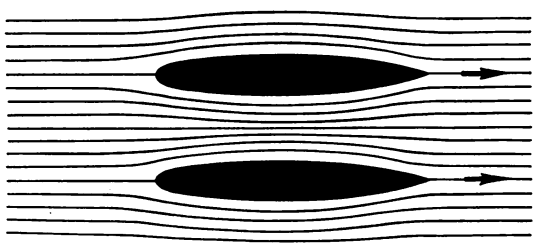


FIG. 16–2. Stream-lines round two ships close aboard at sea

It appears, therefore, that two symmetrical bodies moving through the water abreast one another would be drawn together because of the zone of reduced pressure lying amidships between them. In the case of two ships steaming close aboard this mutual attraction inwards is accompanied by a turning moment tending to force each stem outwards, probably caused by the bow pressure zones being opposite one another. If the rudder was left amidships in each ship they would each immediately adopt an angle of yaw outwards, which would produce a force tending to pull them apart because of the water pressure between them. In fact, as the ships approach the close-aboard position the steering is adjusted as necessary to maintain station, and it is found that when they have settled down abreast one another they are carrying some inward wheel and also have adopted a very small angle of yaw outwards.

While approaching the close-aboard position on parallel courses the two ships overlap one another and the pressure zone of one will lie opposite the suction zone of the other. This state of affairs, in either the approach or departure,

upsets the stream-line pattern and no exact data are available as to where the boundaries of the pressure and suction zones lie. What is known definitely is that in these attitudes larger turning moments arise tending to turn the ships, in addition to the attraction or repulsion forces acting either inwards or outwards; and that these turning moments change direction suddenly with only a small change in the relative positions of the ships. This necessitates a rapid change of rudder from one side to the other in order to keep on course while passing through these attitudes when approaching or disengaging.

So far the action of the propellers has not been mentioned. The propeller suction on the ship is only a small fraction of the hull resistance. It is localised and the sternward wash is of restricted width. Thus propeller race or suction is not important in interaction when two ships are proceeding steadily on parallel courses, although it may have some influence when gaining speed from rest.

Interaction between two ships passing close aboard

The stream-lines and pressures can be determined mathematically for oval shapes and also for sharp-ended shapes approximating to ships. It is not yet possible to calculate the forces on a ship exactly from theory, because the shape of the ship cannot be expressed mathematically. Assurance is afforded by model experiments that the stream-line systems of the mathematical shapes exhibit the leading features of the pressures and suction zones around actual ships.

Figure 16–3 shows the interaction effects that occur when one ship (A) overtakes another (B) on a parallel course, passing through the close-aboard position and disengaging ahead. The effects shown in the diagram were obtained from experiments with models, ship A representing a heavy ship of some 740 ft in length and 100 ft beam, and ship B a tanker of about 570 ft length and 70 ft beam. When close aboard, the distance between the models represented about 50 ft. The figures run from 1 through to 9, the distances under each representing the position of A's stem relative to B's, e.g. in (1) A's stem is 600 ft astern of B's. In each position the forces of attraction or repulsion, and also the turning moments, are shown. The values of these forces are given, to enable a comparison to be made between the various positions, but the nature of the units used to measure these forces need not concern us. The model experiments covered many runs at speeds representing a range of from 10 to 20 knots.

When the bow of A begins to overtake the stern of B each ship experiences a repulsion force outwards. But at the same time there is a slight tendency for each ship to turn inwards (positions 1 and 2).

Dangerous position in the approach

Further on the turning moment in B is reversed (between 2 and 3) and the forces of repulsion change to attraction (4). At this stage there is a potentially dangerous situation, because there is a tendency for the bows of A to swing towards B, and for B's stern to swing towards A, while there is also a tendency for both ships to move bodily towards one another. In practice both ships will have to use wheel and will find steering generally difficult while passing through this position, and if they are too close they may have to take quick and bold action to prevent collision. Thus it is most important not to approach from the quarter on a path that is too close to the wake of the supplying ship.

Abeam position

In the abeam position (5) it is seen that although there is strong attraction there is also an outward-turning moment in both ships. In practice it is found that, provided the two ships are not greatly dissimilar in size, the tendency is for them to be forced apart and to require to carry wheel inwards to maintain station.

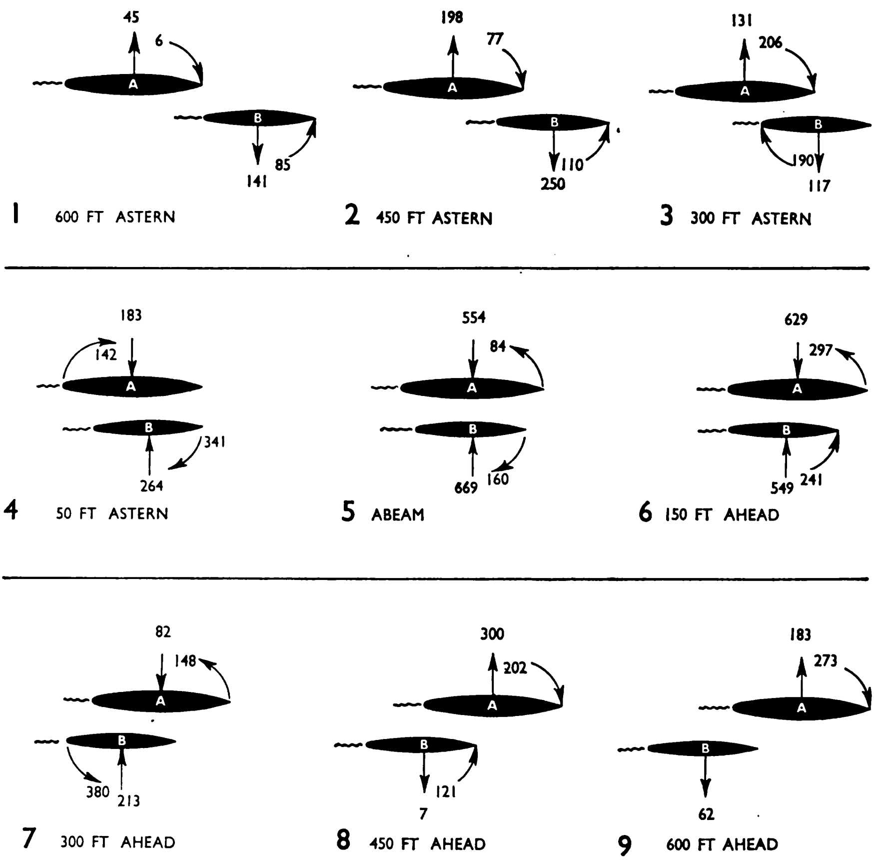


FIG. 16–3. Interaction effects when one ship (A) overtakes another (B) on a parallel course passing close aboard at 50 ft

Dangerous position when disengaging

As A draws ahead from the abeam position it is clear that she will pass through another dangerous position (6 and 7) where her stern and B's bows tend to swing towards one another, while at the same time there is a mutual attraction inwards.

Summary of interaction effects

The results of the model experiments on which fig. 16–3 is based were confirmed by a series of sea trials with a replenishment ship in company in turn with a battleship, cruiser and destroyer. The abeam position was found generally satisfactory for replenishment, because the tendency for the bows to be forced

apart increased as the ships closed and thus constituted a safety factor. When approaching or disengaging from the abeam position, the ships passed through potentially dangerous positions and in these positions noticeable effects from interaction could only be avoided if the ships were kept far enough apart to be outside the zone of interaction.

The extent of the zone of interaction and the strength of the effects vary according to the size and shape of the ships, their speeds and the depth of water. Hence it is difficult to give a general rule as to how to avoid any effects being felt. The forces of attraction, etc. are proportional to the square of the speed, but, because of the improvement in steering control at higher speed, substantially the same rudder angles are required for station-keeping at any speed between about 10 and 20 knots. However, at the higher speeds less time is available to correct mistakes. In shallow water, moreover, the strength of the interaction effects is greatly increased. Advice on approach, station-keeping and disengagement follow in subsequent paragraphs, but it may be said generally that small ships will experience interaction effects when within about 50 ft, and large ships when within about 100 ft, of one another.

GENERAL CONSIDERATIONS

Choice of course

In winds below Force 5 ships can usually fuel or transfer stores when steaming in any direction. However, if the abeam method is being used it may be an advantage to have the wind and sea slightly on the bow of the supplying ship, or of the larger of two ships, so that small ships such as frigates can replenish from the opposite side and thereby gain some advantage from the lee.

In winds above Force 5 ships can use the astern method if they wish, and this may be advisable for inexperienced crews, because the ships are not in such close proximity as when abeam and the results of steering or conning errors are not so hazardous. However, replenishment astern generally takes longer than abeam and if the hose-line carries away the tanker has to haul in all the gear in order to bend on another line. In heavy weather there is also the possibility of damaging hoses with the forefoot or bilge keels.

Choice of course in heavy weather

The abeam method does not suffer from these disadvantages and has been successfully used in very heavy weather. The course recommended in winds above Force 5 is down-swell or -sea. Ships are generally steadier and men do not have to work with the ships plunging into the seas, with water charging about the decks and spray flying everywhere.

It is absolutely essential that the speed chosen is such that the ships' speed is below the speed of the waves. If not, there is the very real danger of surfing (see Chapter 15). If this occurs, a small ship may suddenly find herself in a matter of seconds on a wave-top a full ship's length ahead of her proper station and losing steering control. A reduction of even one knot may cure this tendency.

When approaching a tanker from the quarter in a following gale, the sight of both ships wallowing and lurching in different troughs can be frightening. When the receiving ship gets abeam at about half a cable, however, both ships

are in the same trough, the situation is more comfortable and the receiving ship can finally edge in. Frigates have successfully replenished abeam in the Atlantic downwind in a full gale at a speed of 10 knots.

Choice of speed

Generally speaking, it is advisable to carry out replenishment at speeds of between 10 and 15 knots. Weather naturally influences the choice of speed, as it does the choice of course. Speeds of less than 8 knots are not recommended, because steering control is then greatly diminished. To allow a margin for station-keeping, the speed of the force when replenishing should not exceed 1 knot less than the supplying ship's maximum speed, nor 2 knots less than the receiving ship's maximum, whichever is the less.

Replenishment abeam can be done safely at speeds of up to 20 knots, if using a fast supply ship or between warships. But one must remember the warning that greatly increased interaction effects may occur in depths below 20 fathoms at these higher speeds.

Command and control

It is obvious that the steering when close aboard must be of the highest standard. The Officer of the Watch should see that an experienced quartermaster or helmsman is at the wheel, and should supervise his steering closely. The secondary steering position should be manned, to permit a rapid change-over in the event of telemotor failure. Some captains prefer to take control personally of both the steering and the engine revolutions during the approach and possibly while keeping station during the replenishment. Others have found that it is an advantage for one officer to attend to the revolutions and another to the steering, in the way described below under 'ABEAM METHOD'.

The *distance line* is described in Vol. II. It is used to assist in judging the distance between the two ships, both by day or night.

If the replenishment is prolonged those responsible for conning and steering are under considerable strain, and fatigue may cause errors. Steps can be taken to minimise this by arranging reliefs at frequent intervals. A minor point, but one worth considering, is to avoid choosing a course having the same or similar figures to the revolutions, e.g. steering 100° at 100 revolutions per minute. The changes ordered in steering may get transposed with those for speed, with unpleasant results.

ABEAM METHOD

Approach

For ships of cruiser size and above it is generally considered that the easiest and safest approach is from a position on the beam of the supplying ship. In Fleet replenishments the waiting position will be ordered and will usually be on the beam or fine on the quarter; but whichever position is occupied the approach from abeam is best made by first taking up station about one cable on the beam of the supplying ship, and then closing gradually from there. A 5° alteration inwards and a slight increase of speed will close the gap to 100 ft or so within a few minutes. A closer approach is not necessary for making contact by gunline, and interaction effects may be felt inside this distance. A more

spectacular approach, with a bolder alteration inwards, will save little time and could be awkward if misjudged. Moreover, the result might well be unsettling to the supplying ship and to ships replenishing on her other side.

Smaller ships, with more rapid acceleration and deceleration, may approach from the quarter, but although this method will enable contact to be established slightly sooner, particularly if the waiting position is abaft the beam, there will usually be some delay in settling down to the exact speed of the supplying ship. In order to avoid interaction effects while the ships are overlapping during the approach, a closer approach than 100 ft or so should never be attempted, observing that some deterioration in steering control will certainly be felt as speed is reduced.

Aircraft carriers normally replenish on their starboard side, whether supplying or receiving, so that operations can be seen from the bridge, and to avoid the angled deck.

Correct station

If ships are of similar size, interaction effects are least noticeable when directly abeam; and if of greatly dissimilar size, when the smaller ship is in the intermediate area between the bow and stern pressure zones. But the precise position of the receiving ship relative to the supplying ship during replenishment will be governed principally by the positions of the equipment in each ship.

Maintaining station

It is usual for the receiving ship to keep station on the supplying ship, but there may be occasions when the receiving ship is the less manœuvrable of the two and it is preferable to reverse the procedure. It is of the first importance that the ship being stationed on maintains a steady and accurate course and speed.

It is generally considered that keeping close station abeam is simplified if two officers are employed, one watching the distance line and adjusting the course and the other adjusting the speed (either by watching a mark in the other ship, or the transit of two marks, or by watching the angle which the distance line makes with the side of either ship). In most ships it is the practice to have the distance line well forward, so that it will indicate a sheer before the distance apart of the ships at the pivoting point has changed. The officer responsible for the course will find it necessary to watch the compass continuously, and to make a frequent check of the quartermaster's reactions by noting the movement of the rudder indicator. It must be remembered that whenever the rudder or course is adjusted in order to overcome interaction effects, it is probable that the revolutions required to maintain station will also have to be altered.

In good weather conditions by day, station-keeping should present no problem provided quartermaster and engine room are warned of the importance of using small angles of rudder and gradual adjustments of revolutions. The course should be steered by compass, and direct rudder orders should not be given except in emergency. The usual graduation of revolution telegraphs in two-revolution steps should permit sufficiently close adjustment of speed, but it may sometimes be found necessary to order an intermediate setting by telephone.

Keeping station in rough seas is much influenced by the choice of course, and the remarks on this subject earlier in this chapter should be noted (see page 377).

One must be alert to apply bold and quick adjustments to both rudder and revolutions in bad weather.

Night replenishment, whether in peace or war, is usually carried out with ships darkened. It is generally found that station-keeping is easier when neither ship is showing any bright sources of light to cause glare and confuse the judgment of distance. A small pin light forward to indicate the fore-and-aft line from the Pelorus may be helpful in the receiving ship.

Alterations of course

When replenishment is in progress, alterations of course by a force are usually ordered in steps of 20°. Individual replenishment units alter course in smaller steps. The primary method of control of the turn is by telephone, but voice radio or visual signalling may also be used.

Disengaging

Disengaging is best effected by a *slight* alteration outward and a *slight* increase of speed. It is usually sufficient for the disengaging ship to put her rudder amidships if she has previously been carrying inward rudder. Large alterations of speed and large rudder angles should not be used when within half a cable or so of the supplying ship, because the effects are likely to be felt by her and by any other ships replenishing from her. The practice of disengaging by a large increase of speed on the present course is particularly objectionable. Not only will it upset the supplying ship, but it may also result in a dangerous yaw inwards by the disengaging ship because of the interaction effects already described.

It is worth pointing out here that a ship initially on the bows of the supplying ship and intending to drop astern into the abeam position is also liable to get into trouble. If she reduces speed, without some alteration of course outwards to counteract the inward turning moment caused by interaction, she is liable to yaw inwards and fall across the bows of the supplying ship.

When disengaging it is important to keep a lookout for traffic astern and on the disengaged side.

ASTERN METHOD

Approach

In the astern method, the normal method of passing the hose from the supplying ship is by streaming a line with a float on the end, the line being grappled from the receiving ship's forecastle. In this case the approach is made from right astern. Having grappled the hose line, the receiving ship steams ahead and heaves it in. By the time the hose-end reaches the fairlead the marker buoy should be abreast her bridge. This marker buoy is veered by the supplying ship to such a distance that when it does come abreast the receiving ship's bridge the hose will be towing in a bight of about 100 ft (fig. 16–4).

An alternative method of passing the hose is by gunline, the receiving ship closing the supplying ship's quarter to make contact. Care must be taken not to overlap excessively, nor to get too close, as interaction effects are particularly noticeable in this position and especially when reducing speed to drop back again to the astern position. Obviously, the gunline method is not practicable when ships are already replenishing abeam on each side.

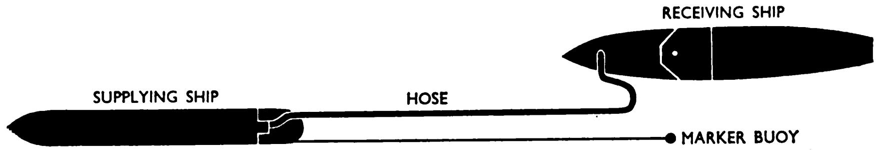


FIG. 16–4. Replenishing by astern method

Maintaining station

Station-keeping is considerably simplified in the astern method, and slightly larger errors ahead and astern of station are permissible. It is essential, however, to maintain the bight in the hose as narrow as possible, and steering must be carefully watched. The wider the bight the greater the strain on the hose. On the other hand, one must avoid at all costs touching the hose with the forefoot, because if there is any motion on the ship even a graze is liable to part or damage it.

Speed

In the astern method, speed is restricted by the strength of the hose, but provided the bight is kept fairly narrow—not more than about 40 ft across—speeds of up to 15 knots should be practicable in calm weather. Rough seas will bring greatly increased strains on the hose and station-keeping will be more difficult. Speeds of above 10 knots should not normally be attempted when pitching heavily.

Alterations of course

When a single ship is replenishing by the astern method, no special procedure is necessary for altering course. When two ships are replenishing astern simultaneously, or when the abeam method is also being used, it will be necessary to signal alterations in steps, as previously described.

Disengaging

When the hose has been passed by the float method, the receiving ship disengages by dropping astern, veering the bight of hose line as she goes. But she should only drop astern 20 to 30 ft, otherwise there is a danger of parting the gear on the forecastle.

If the gunline method has been used, the receiving ship must regain station on the quarter of the supplying ship in order to pass back the hose line.

TRANSFERRING BY INFLATABLE LIFERAFT

In heavy weather at sea, if conditions are too rough for boatwork a small inflatable liferaft (e.g. a 10-man raft) affords a safe and practical method of transferring small quantities of stores or men between two ships under way but stopped. The liferaft is rigged with an outhaul consisting of 120 fathoms of 2-inch manila which is passed over to the receiving ship by the supplying ship, which retains a similar inhaul. The raft is normally dropped by means of a trip-hook on a purchase slung from a suitable derrick, such as an ammunition derrick. Unless specially strengthened, the liferaft should not be hoisted in with

the load. Details of the rig required are given in Vol. II, while the following remarks deal with the handling of the two ships during the transfer.

The receiving ship remains stopped, lying beam to wind and sea with no way on the ship. The supplying ship may then approach downwind and -sea,

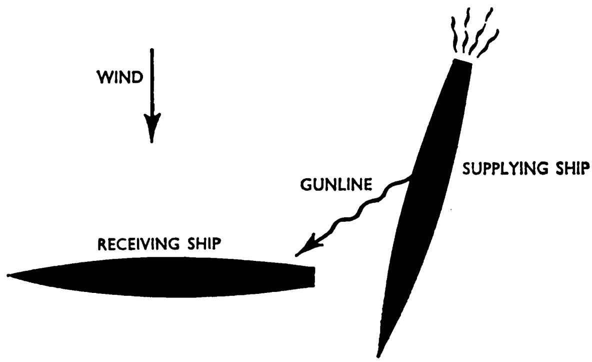


FIG. 16–5. Transfer by liferaft—the approach

passing close to the stern of the receiving ship (fig. 16–5). As the stern of the receiving ship is passed a gunline is fired, and while this is being checked away the supplying ship is brought to rest and held stern to wind and sea. The

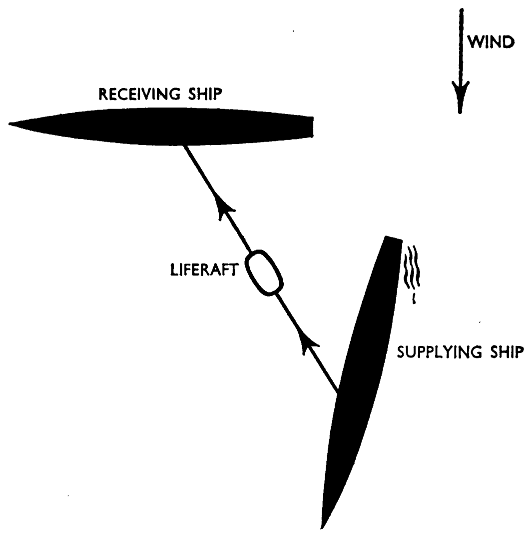


FIG. 16–6. Transfer by liferaft—the transfer

supplying ship is then manœuvred as necessary to keep the stern reasonably clear of the other ship. The gunline is followed over by the outhaul, and as soon as the strain comes on the outhaul the raft is slipped and veered across on the inhaul to the lee side of the receiving ship (fig. 16–6). If the stern of the supplying ship now falls off the wind in the direction of the receiving ship (fig. 16–7) it may be difficult to use the engines to correct this without fouling the gear. To

avoid this difficulty snatch blocks should be placed in one or two positions abaft the derrick and sufficiently high up on the engaged quarter to enable the inhaul to be snatched in and kept clear of the water when necessary. To use a derrick more nearly amidships than right aft has the advantage of keeping the gear well away from the propellers.

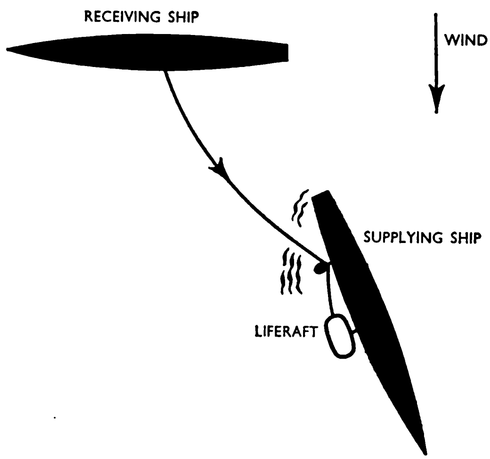


FIG. 16–7. Transfer by liferaft—the recovery

When the liferaft has been unloaded by the receiving ship it should be hauled back roundly until under the derrick. If the derrick is amidships the supplying ship will now be free to work her engines so as to give a slight lee to the hoist, but should avoid getting beam-on to the wind, because heavy rolling will make recovery more difficult.

Alternative method

An alternative method that avoids the nuisance of keeping the inhaul and outhaul clear of the screws is simply to drop the liferaft two cables or so downwind of the receiving ship and then get clear to windward. There must be an experienced man in the raft, wearing a lifejacket and with a lifeline secured to the raft. The receiving ship then approaches the raft downwind, stops alongside and embarks the load. If recovery is necessary it may be done in the same way. At night the raft must have a light and the crew a waterproof torch.

CONCLUSION

Men-of-war are particularly vulnerable while replenishing at sea because of their limited manœuvrability. Time spent on replenishment is not available for active operations against the enemy. For both these reasons it is clearly desirable that ships should replenish as quickly as possible.

On the other hand, the point of replenishing at sea is to keep ships at sea and minimise their time in shore bases. If collisions occur or gear is damaged through faulty shiphandling, ships will be obliged to return to bases for repairs and the aim of the operation will be frustrated. Efficiency is not achieved by

speed if it is at the expense of sustaining unnecessary damage. It may therefore be unwise to insist upon too much competition between ships to reduce replenishment times, especially if they have only recently worked up. As a commission progresses and all hands from the captain downwards improve their skills and become accustomed to their jobs, it can be expected that replenishment times can be continuously reduced.

CHAPTER 17

Ice Prevention and Handling Ships in Ice

This chapter deals with two related subjects: first, the dangers from ice accumulating on the superstructure and how to prevent them, and secondly, the handling of warships in sea ice. Men-of-war are not generally designed for operations in ice and should usually try to avoid it, but on certain occasions it may be essential for them to enter the ice, and the aim of the latter part of the chapter is to advise on how to minimize the hazards entailed.

A number of publications exist that would enable a more detailed study of ice to be made, and these should be consulted if large-scale operations in icy waters are planned. For example, the *Pilots* or *Sailing Directions* and *The Mariners' Handbook* published by the Hydrographic Department, Admiralty, contain much useful information on the characteristics of sea ice, its extent and nature in the various Arctic and Antarctic regions, on ice navigation and weather conditions in high latitudes. Another useful Hydrographic Department publication is H.D.394, *Notes on Convoying in Ice.* The U.S. Navy Hydrographic Office issues a *Manual of Ice Seamanship*, which covers ice operations generally, including the provision of specialized equipment and the use of specialized ships such as icebreakers. The *Admiralty Manual of Navigation*, Vol. 1, contains a chapter on navigation in ice.

ICE ACCUMULATION

Warships operating in high latitudes must be prepared to deal with heavy icing of the superstructure, weather decks and exposed equipment. Under certain conditions tons of ice can form on the upperworks of a ship in a matter of hours and there are many cases of ships having capsized and been lost with all hands from this cause.

Causes of ice accumulation

Ice accumulation may occur from three causes:

1. Fog with freezing conditions, including frost smoke (or Arctic smoke). This is low-lying fog giving the appearance of the sea steaming and caused by very cold air overlying relativelv warmer water.
2. Freezing drizzle or freezing rain.
3. Sea spray or sea water breaking over the ship when the air temperature is below the freezing point of sea water, i.e. below 29° F.

It is not often that conditions 1 and 2 cause the accumulation of a heavy weight of ice, but under certain conditions moisture may freeze rapidly on every part of the ship, causing the formation of dangerous top weight on masts and aerials in a few hours. The phenomenon is sometimes called *black frost* or *black ice*. The Officer of the Watch must be on the lookout for this, particularly at night. There may not be time to use the methods of ice removal described below

and the only remedy may be to steam quickly away from the area towards warmer air.

It is more common for condition 3 to cause ice accumulation, particularly when much spray or heavy seas are continuously blown over a vessel by strong winds in temperatures of 29°F or lower. Frigid winds may blow at gale force for days on end, and the only prudent course may be to steer away from the wind for a period, at the same time mobilising all hands to clear the ice.

Dangers of ice accumulation

The danger of additional top weight caused by ice on masts, etc., resulting in loss of stability, is perhaps the most serious. However, there are also the dangers of injury to personnel working on slippery decks, and the difficulties of working and handling iced-up armament and equipment. Radar aerials and similar apparatus may be damaged by the load of ice formed on them. Methods of combating the dangers consist both of means to prevent the ice forming, or if formed, to prevent it adhering to structures; and also of means to remove the ice when formed.

ICE PREVENTION

Housings, shields and covers

Housings and shields are made to protect armament and other mechanical equipment liable to exposure to heavy spray. Ships are constructed in such a way as either to prevent water entering exposed deck equipment such as davit pedestals, lockers, etc., or to permit rapid drainage. If housings or shields are impracticable, covers of waterproof canvas or P.V.C. are supplied, to cover, for example, exposed working parts of armaments, such as breech mechanisms, or capstans, windlasses, winches, etc.

For boats' falls it is possible to make a canvas sleeve to cover both blocks when the boat is hoisted. The sleeve should be open at the bottom end, and have a slit through which the hauling part of the fall is led away. It should fit snugly over the upper block so that it can be left in place while the falls are worked. Blocks for signal halyards can be protected with similar covers. Such covers can be coated with the appropriate de-icing grease, compound or paste as described below, and should be dry when it is applied.

No satisfactory way of preventing ice accumulation on Perspex has yet been developed.

Heating of bridge windows

Screens of special multi-ply glass, electrically heated by means of a fine wire network embedded during construction, are generally fitted to enclosed bridges of H.M. ships. An electric loading of 150 watts per square foot of glass area exposed is sufficient to prevent ice formation under the worst weather conditions likely to be met. Power-operated wipers and fresh-water sprays are also used in conjunction with these heated windows.

Ice-phobic dressings

Special dressings may be applied on surfaces where shielding or heating would be too complicated. These dressings do not prevent the ice from forming,

but they do prevent it from sticking, so that it is easy to knock it off without damaging the underlying structure. They are not necessary on surfaces bounding heated compartments (e.g. decks), because the ice layer nearest to the plating melts and it is as easy to detach ice from these surfaces as it would be if they were coated with the dressing.

The following dressings are available:

Grease L.G.380. This is used for the lubrication of the fine mechanisms of armaments, such as guns and torpedoes, not directly exposed to the weather. It should be liberally applied to prevent water from entering the mechanism and freezing there. The grease remains soft down to $-70°$ F, but is readily swept off by spray, so that mechanisms so treated should have covers, as described above, or a top dressing of de-icing compound.

De-icing compound. Coarser mechanisms—such as those of anchors and cable gear, bottlescrews and slips generally, working parts of stanchions, roller fair-leads, door hinges, valves, ventilators, winches and davits—that are directly exposed to spray should be covered with de-icing compound. This is an asbestos grease which is not easily washed off, so it can be applied before leaving harbour. It can be put on by hand or with a trowel; it cannot be brushed and cannot be melted. On plain surfaces the film should be as thin as possible. The compound is *not* a lubricant for fine mechanisms. Therefore such mechanisms or joints should first be packed with Grease L.G.380 and then covered completely with the compound.

De-icing paste can be used for the treatment of large surfaces such as bridge superstructures, gun housings, etc. It is a soft mineral jelly that stiffens on exposure to air. It is unnecessary to use it on surfaces bounding heated compartments, as explained above; and because it is greasy it must never be used on decks.

No de-icing dressings should ever be used on cordage. To remove the dressings, scrape off as much as possible and then use a rag soaked in kerosene or vaporising oil.

Steam heating

Steam heating coils are fitted in certain places to assist in keeping exposed armaments and equipments free of ice. For instance, they are usually fitted close to the revolving bases of large gun mountings and directors. Selected watertight doors giving access to weather decks in very exposed positions are each fitted with a steam coil surrounding the door frame.

Electric heating

In some ships steam is not available for heating, and in others its use is considered uneconomic or impracticable; as an alternative electric heating is used. The heating arrangements may be incorporated in the design of particular equipments, but in many cases current is led to convenient sockets for use with portable heaters. These sockets are fitted to many types of armament, at motor-boat stowage positions and boat booms for warming engines, at stowage positions for mobile cranes, on the fixed structure adjacent to signalling projectors and for any other exposed mechanisms where heating is considered necessary and steam is not available.

ICE REMOVAL

By hand

Ice can be broken away and chipped off, using mallets, ice picks and spikes, scrapers and stiff brooms. Caution must be used to avoid damage to metal surfaces such as chains, reels, stanchions or railings. Special care must be employed around electric cables, gun mountings and other machines or mechanisms. With this method block ice can be removed by splitting it with the sharp-pointed ice picks or spikes which are supplied to ships. Generally, hand picks 2½ lb to 3 lb (Patt. 5972) are supplied for clearing large accumulations of ice round gun mountings, capstan fittings, etc., while ice spikes with 4-ft handles (Patt. 5973) are designed for use in clearing superstructures. The handle of the spike should be cut as necessary for use in removing deck ice, while hand ice prickers (Patt. 1865) should be used in confined spaces where the pick is not suitable. In the absence of ice prickers, sailmaker's prickers (Patt. 1868 or 1870) may be substituted.

Very little effort is required to detach large blocks of ice by this method. The procedure is to mark out a line of cleavage with the spike or pick by means of a number of jabs close together; then, by a deeper penetration of the implement in the line of cleavage at one or two points as necessary, split off the block. A narrow channel should first be cleared and then the blocks split off into the clear space, working progressively over the surface.

By hose

Sea water, even at temperatures as low as 30° F, is an effective de-icing agent when applied by hose with standard branch-pipe nozzles and at ordinary fire-main pressures (50 lb per sq. in.). With greater pressures the effectiveness of this technique is appreciably increased, and a nozzle of large diameter will be found to give better results than one of small diameter.

The jet should be played on the surface of the block ice until a slot of penetration is achieved. Large masses of ice can then be dislodged easily by playing the jet on the joint line of ice and steel until the adhesion is broken. In all cases, however, dislodged ice must be removed quickly and not allowed to build up on the decks.

De-icing guns

Guns can be fitted with a special harness incorporating a textile instantaneous fuze. The harness is placed over the barrel, and if ice forms on top of it, the ice can be split off by firing the fuze. Thus guns can be prepared initially by fitting the harness in harbour, and later cleared of ice immediately before they are required for action. The harness consists of a canvas muzzle and a number of securing bands which fasten, by means of quick-release buckles, round the barrel. The securing bands are linked by longitudinal strips to which the cordtex fuze is attached. This type of harness is suitable for guns of 3-in. to 6-in. calibre.

Hot air

Moderately hot air (180° C) tapped from the compression stage of turbine-driven fire pumps can be effectively used for the removal of ice. This method is advantageous for use around instruments and other areas where chance of

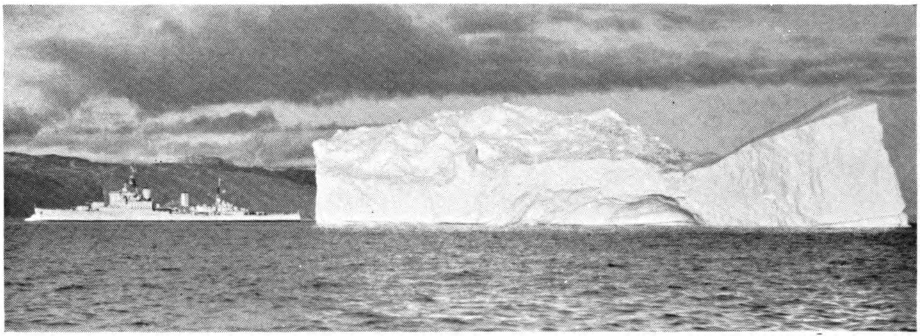


FIG. 17–1. Typical North Atlantic iceberg with a cruiser to indicate size

FIG. 17–2. Typical Antarctic icebergs surrounded by pack-ice

FIG. 17–3. Working through pack-ice in the Antarctic

damage makes other techniques inadvisable. The jet may also be used to undercut or slot other ice so that it can be removed easily by manual means.

Steam jet

As with hot air, this method may be used around instruments, etc. or as an occasional aid to manual methods. Its big disadvantage is the high consumption of fresh water.

HANDLING SHIPS IN ICE

As already stated, the following remarks apply only to the rather limited operations in ice that are likely to be met with by men-of-war not specially fitted for working in ice. Although the descriptive terms for ice in its many forms are given in the *Admiralty Sailing Directions*, it may be helpful to begin by restating some of the more common definitions.

Sludge, or Slush. The initial stage in the freezing of sea water, when it assumes a greasy appearance and a scum of ice crystals is formed on the surface. Sludge is little hindrance to navigation, though it will reduce the ship's speed for a given number of revolutions and may choke circulating water intakes, if these are near the surface. Bottom logs, sonar, etc. need not be housed in sludge, though a towed log becomes useless. Sludge should not be confused with ***brash*** or ***mush***, which are terms applied to small fragments of other forms of ice, e.g. the wreckage of drift-ice.

Pancake-ice. The next stage in development after sludge. Pancakes from 1 to 6 ft across and approximately circular in shape form after two or three days of freezing temperature. Before consolidating into floes, these pancakes may be a foot or more in thickness. They generally have raised rims caused by the pieces striking against each other. In an area of pancake-ice the pieces are usually crowded together, but with unfrozen water in the many spaces between their points of contact. The majority of H.M. ships will not be able to maintain their normal cruising speed in pancake-ice without risk of damage to plating. If forced under the ship this type of ice may damage a bottom log or sonar dome and can bend or break a propeller blade. It is impracticable to use any form of towed sweep in pancake-ice.

Pack-ice. Any area of sea-ice other than fast-ice, which is ice that has developed from shorewards, i.e. is 'fast' to the coast. See fig. 17–2.

Drift-ice. Loose, very open pack, in which the majority of floes are of greater size and age than pancake-ice but are more widely separated, so that the area of clear water is greater than that of ice. There is no clear distinction between drift-ice and open pack, but the former term is applied to smaller and lighter floes, which are often soft and in a state of decomposition; in the latter case they may have relatively hard underwater spurs caused by the melting back of the exposed ice. Drift-ice should be treated with respect, and when the larger floes cannot be avoided they should be approached with caution. Drift-ice will restrict the use of sweeps, etc. in proportion to the frequency of the floes and the possibility that the ship may have to steam dead slow or stop.

Open pack. This term is applied to an area of heavier floes, for the most part not in contact but with many leads and pools through which a ship can be navigated with caution. See fig. 17–3.

Close pack. The floes are mostly in contact and will block the passage of any but specially strengthened vessels.

Deliberate and routine passages through pack-ice should only be attempted by specially equipped vessels, but more or less impromptu operations in drift-ice and open pack may be required of any class of ship. The majority of H.M. ships are quite unsuited for forcing a passage through close pack, and it must be clearly understood that when such conditions are discussed in subsequent paragraphs, the circumstances in which a ship is compelled to adopt these ice-breaking tactics are assumed to be dictated by emergency.

DAMAGE FROM ICE

The shiphandling problem is best approached by an examination of the type of damage to which a man-of-war is subject when working in these exceptional conditions. The chief source of weakness is the bow plating, which, generally speaking, will be unsuitable for impact, except at very slow speed, with large masses of hard ice of a greater thickness than one foot, the average thickness of pancake-ice. Although thicker floes may be pushed aside, a large and unyielding floe is liable to bend the stem, or may tear open the plating as the ship slews round after impact. The majority of floes are at least 3 ft thick, and, unless composed of very soft ice, cannot be penetrated with safety.

Propeller blades are very liable to bend or fracture from impact with ice, though in some warships they are so deeply immersed that only an up-ended floe is dangerous. On the other hand, the majority of warships are fitted with multiple screws, which are much more liable to damage than a centre-line screw. Similarly, twin rudders are a great disadvantage when working through ice. Trim by the stern is usually advisable to obtain deeper immersion of propellers and rudder, but an extreme 'bows-light' condition will have an adverse effect on manœuvrability, and should be avoided. Bilge keels are liable to be wrenched away from the hull on impact with ice forced under by the ship's advance. Other hull projections such as scupper guards, eye-bolts, and even rivets, may also be the cause of serious leaks.

In the extreme case of the ship being beset in the ice, the square cross-section of the average warship's hull will render her particularly liable to be crushed.

OPERATING IN PACK-ICE

Operations in drift-ice

Obviously the only effective way of avoiding damage is to avoid contact with the ice. This may be possible at slow speed in drift-ice—that is to say, very open pack with large areas of clear water between the floes. When the floes cannot be avoided they can often be fended off with long staves. This may not be practicable from the forecastle, because of its height, but should be quite feasible from the quarter deck, where it is of particular importance owing to the tendency for ice to be drawn in under the counter, especially when the ship is swinging. An extempore propeller guard rigged at the waterline on each quarter may give some protection, but it will be difficult to fit effective securing arrangements. Wooden catamarans, with their outer corners faired off, have been tried, but these are liable to up-end and foul the propellers in much the same manner as a floe.

Drift-ice may sometimes be soft, so that floes will break up readily with little risk of damage to the ship's hull. Nevertheless, if other considerations permit, evasive action should be the rule. The behaviour of an up-ended floe is unpredictable, and although the ice may not be sufficiently hard to cause direct damage to propellers or rudder, large masses jammed in the vicinity of the 'A' brackets, or between rudder and hull, or on the rudder itself, can be the cause of a breakdown. A careful propeller watch is essential so that the propeller can be stopped when a floe or block cannot be fended clear. At the same time a propeller dragged through the water for any considerable period is more liable to accumulate debris, and the opinion is sometimes expressed that the blades are more liable to fracture when stopped than when turning slowly. Certainly in much broken ice it will be better to keep the propeller rotating, as it will act as a guard for the rudder, so that only pieces of ice which have been cut up by it will be allowed to pass. In such conditions it is advisable to use only a few degrees of rudder.

Ship-handling in drift-ice is largely a matter of careful conning at moderate speed. At high speed, greater concentration and skill are required to avoid the floes, and a small error of judgment may result in serious damage. In this connection it should be noted that 'full speed' in the majority of publications on ice navigation refers to the maximum speed of the average small merchant vessel, some 10 to 12 knots.

This emphasis on manœuvrability when working in drift-ice leads to the conclusion that large warships, e.g. cruisers and above, are eminently unsuitable even for these comparatively easy conditions. Destroyers and frigates also, by reason of their light construction and projecting propellers, come in the category of vessels which are best kept clear of any area of ice unless operational requirements justify the virtual certainty of damage.

Working through open pack

When working through open pack (as defined) the need for manœuvrability is of even greater importance, because the requirements are then not only handiness in negotiating tortuous lanes and leads rather than individual floes, but also the ability to select the best points of cleavage and the capacity to back and fill readily.

Working through close pack

Pack-ice is continuously in motion under the influence of wind, tidal stream, or current. As a result of the varying movement of adjacent masses, there will be a tendency for cracks, lanes and leads to open and close from hour to hour and day to day. Swell will also tend to break up the ice, and in narrow or shallow waters the vertical movement of the tide will have the same effect. Conversely, this complex movement of the ice will result in areas of pressure, with the formation of ridges. Entry into an area of ice which is verging on close pack is therefore a step which, in an unprepared ship, should never be taken without preliminary reconnaissance. The choice of the point of entry will be governed primarily by the position of the nearest suitable lead or area of open water.

The leads and lines of weakness in the pack can best be seen from aloft, and it is therefore essential that the crow's nest should be manned. If possible, the ship should be conned from there. If air reconnaissance is available, observers should be carefully briefed, in particular so that pools of water lying on

unnavigable ice may be recognised as such and not erroneously reported as leads or open pack. Regions of pressure, as evidenced by tenting or rafting, must be avoided at all costs.

Breaking through an area of close pack

If one's destination lies within an area of close-pack or beyond it, there may be a choice of entering the ice from either the windward or leeward side. The latter is preferable, because the ice there will be less compact and the sea calmer. Although the dangers of entry into the windward side of the pack may not appear too formidable at the time, it should be assumed that ice conditions in that area are deteriorating and that pressure is building up. When there is no lee, consider lying off and waiting for a change of wind. Entry should be made at the lowest speed which will give steerage way, but once the bow is in the ice and cutting it or pushing it to one side, revolutions should be increased again to avoid losing headway. The ice should always be entered on a course perpendicular to the line of its edge, and the same rule applies when breaking out of the pack into open water.

Once in the pack, the ship will often move in the direction of least resistance, irrespective of the position of the rudder. Bursts of power against full rudder may frequently be necessary to keep her head in the required direction and to prevent the stern swinging against the ice. In twin-screw ships a propeller watch is essential to warn the bridge when ice in contact with the hull is approaching the propellers on each side, in order that the propeller may be stopped until the danger is past. Do not gather sternway into ice which has closed in astern. If it should be necessary to back out from unyielding pack, any pieces of ice which have closed in astern should first be washed away by ahead revolutions; but if collision with ice appears inevitable when the ship has sternway, propellers should be stopped and the rudder put amidships.

The ship's bow should never be forced into a narrow lead between large floes if there is any movement tending to bring the floes together. Either one floe should be pushed away to widen the lead, or a part of one floe should be broken off to achieve the same object.

In an unprotected ship it is inadvisable to force on through ice which is becoming so compact that the ship seems unlikely to be able to leave a clear lane astern of her. To continue in such conditions may result in the ship being brought to a standstill and yet unable to manœuvre herself astern, or she may be nipped between two floes. It is better to stop and await more favourable conditions. By so doing, possible damage will be avoided, fuel will be saved, and in all probability no time will be lost. The decision whether or not to keep going is influenced by operational requirements and by whether the ship is entering or breaking out of the ice. If the ship has just entered the ice and it is early in the season, it is best to stop and wait; whereas if it is near the end of the season, or if there is only a little way to go to reach open water, it is advisable to keep going. In low visibility and at night the ship should always be stopped, since the best direction in which to work can no longer be seen.

Stopping in the ice

When stopping, a patch of clear water should be chosen, if possible, and the ship laid alongside the ice so that the wind keeps her against it. No ice anchors

are required if this is done, and any closing-in of the ice due to the wind will be seen in good time. If no clear water is available the ship should be stopped between small floes rather than large ones, so that if the ice subsequently closes up under pressure, some of the pressure will be absorbed by the small floes rafting or being forced under the ship. Once the ice has met under the ship the danger of the ship being damaged by the pressure is greatly diminished.

If it can be avoided, the ship must never be stopped between two large floes, particularly if their edges are irregular in shape. If such floes should move together under pressure and a point of ice should bear against the ship's side it will almost certainly damage it, and quite possibly stove it in. If the edges of the floe are straight, the pressure will be borne over more of the side, but even so there will be danger of being crushed.

The best place for a ship to winter in is a shallow, enclosed bay—enclosed so that there can be no pressure in the ice, and shallow so that no icebergs can drift in to menace the ship. She should be secured on what is normally the windward side of the bay.

Towing in ice

Should it be necessary to tow a disabled ship through pack-ice, the tow should be kept as short as swell conditions permit, so as to give greater control of the towed ship and to minimise the chance of floes drifting between the two ships and parting the towing hawser or damaging the other ship. When there is no swell, it should be possible to keep the tow clear of the water. When towing in this manner, at very short stay, the stern of the towing ship will require to be well fendered, and prompt and skilful action will often be necessary to avoid collision as the tow rides ahead. The wash of full power from the towing ship can sometimes be used effectively to keep the other ship clear.

The behaviour of the ship in tow must be carefully watched, so that alterations of course in leads, or when avoiding floes, may be made without putting her into the ice. When towing at very short stay, two towing hawsers may be used with advantage, as widely spanned as possible.

The strain on the towing hawsers will be very severe if the towed ship comes in contact with heavy ice, and special precautions must be taken against nipping and chafing at the lead-in. Bollards should not be used as securing points if this can be avoided; they are liable to be torn out by the sudden jerks caused if ice is encountered when towing at short stay.

Icebreakers are usually constructed with notched sterns to take the bow of the towed ship, thus avoiding the difficulties and dangers of working through close pack with a free tow at short stay. The towed ship is hauled close up into the stern indentation, and icebreaker and tow work as one unit. It may be necessary on occasions for a ship not designed for the purpose to attempt to tow in this manner, if towing at short stay proves impracticable. Evidently in such circumstances the chief concern of both ships will be adequate fendering.

DANGERS WHEN BESET

Releasing the ship when fast in the ice

This problem is discussed in the *Sailing Directions*. The majority of H.M. ships will not be prone to run up on the ice, and the remarks on this particular

situation will only be applicable to such small ships as have a rounded forefoot. Any of the expedients described may, however, be of assistance in freeing any class of ship, in whatever circumstances when she is fast or beset. Explosives will sometimes be the only effective method of shifting the ice, particularly when the ship has attempted to widen a crack and has become nipped. In such cases, small demolition charges about 10 ft clear of the ship's side where the pressure seems greatest will often cause a temporary movement of the floes that will enable the ship to come astern, provided her engines are turning full speed astern when the charges are detonated.

Risk of damage

The danger to a ship beset depends chiefly on the underwater shape of her hull, the time of year and the locality in which she lies. A ship with deep, straight sides is more likely to be damaged than one with a rounded section which will rise as the pressure increases and will allow the ice to meet under her. A ship temporarily beset in the spring or summer is unlikely to be damaged if she is caught in an area of little pressure.

A well-built ship beset and forced to winter in the open pack will not necessarily come to any great harm provided she does not subsequently drift into an area of pressure—for instance, an area where the ice is being pressed against a coastline—and provided she has adequate reserves of fuel and stores.

Icebergs are another source of danger to a ship beset, particularly in the Antarctic. Owing to their great size and draught these may move independently of the pack, ploughing through the floes and building up a 'bow wave' of pressure ice which can crush a ship if unable to manœuvre clear. The smaller Arctic bergs are generally not such a menace in this respect.

CONCLUSION

Shiphandling technique in pack ice is dependent basically on the strength, power and manœuvrability of the individual ship. A lightly-built man-of-war such as a destroyer or frigate will not stand up to impact with heavy floes; her propellers are extremely vulnerable, and her hull will quickly be crushed in pressure ice. Heavier warships are no better-suited to ice operations, for, although their armoured sides can better withstand pressure, their thin bow plating and projecting propellers are generally as vulnerable as those of the smaller ship. Unless specially built for ice operations, a warship must therefore be handled with the object of avoiding impact with thick ice, unless taken at very slow speed directly on the stem. Only the smaller ships have the necessary manœuvrability to achieve this object.

The ability to differentiate between hard ice and soft ice and between passable and impassable pack, to recognise weathered floes with their dangerous underwater spurs, to detect lines of weakness and to select the most suitable leads, etc., can only be gained by experience, and no amount of textbook knowledge will stand in its stead. Sea ice is a navigational hazard of the first order, and should be accorded all due respect. On the other hand, it is a hazard which can be greatly minimized by skilful shiphandling and a sensitive appreciation of the capacity of the ship to withstand damage.

INDEX

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